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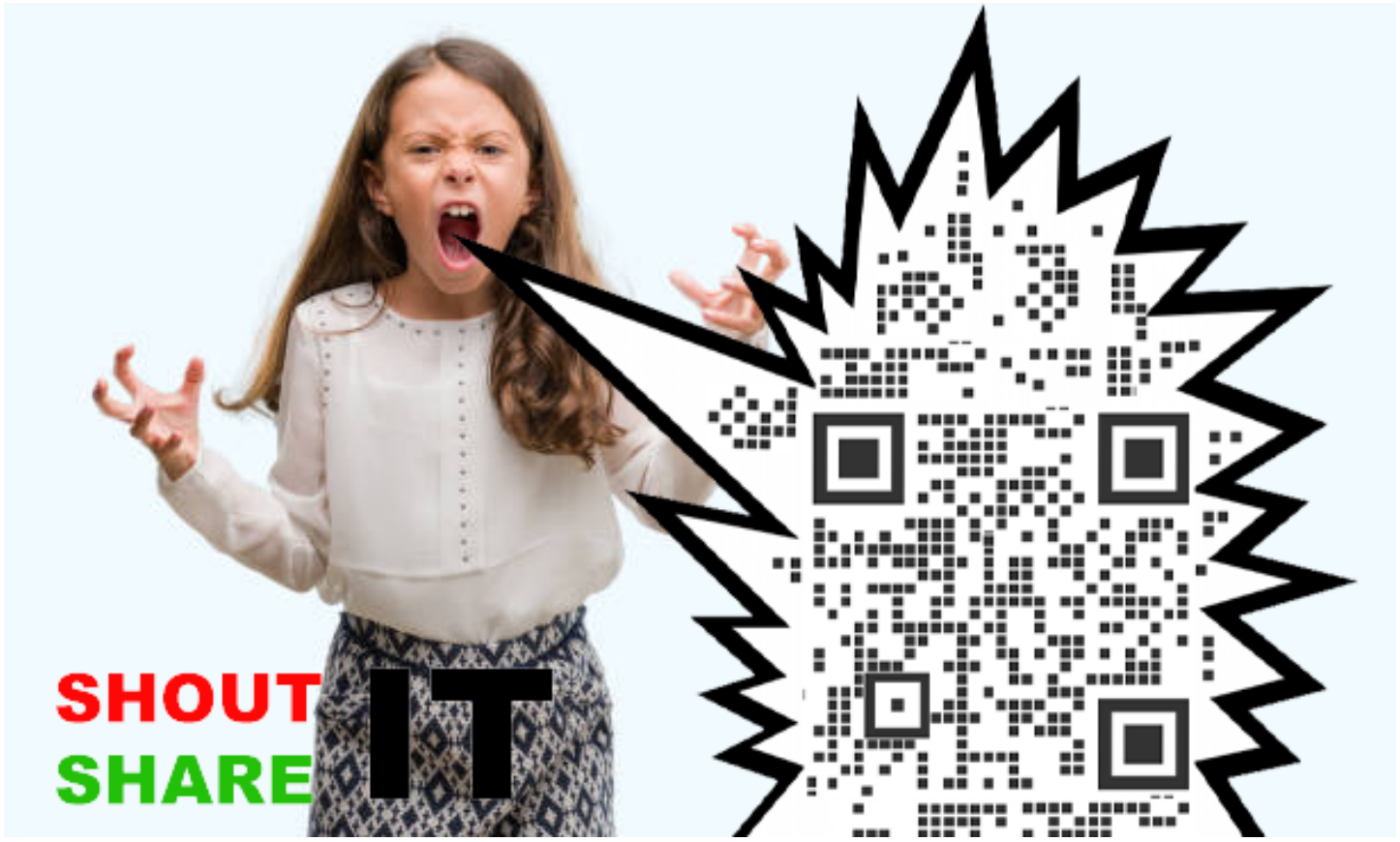
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UNITED STATES DEPARTMENT OF AGRICULTURE

DEPARTMENT BULLETIN No. 1402

Washington, D. C. ▼ May, 1926

TIMBER GROWING AND LOGGING PRACTICE IN THE CALIFORNIA PINE REGION

MEASURES NECESSARY TO KEEP FOREST LAND PRODUCTIVE AND TO PRODUCE FULL TIMBER CROPS

By

S. B. SHOW, Silviculturist, Forest Service

Introduction by

W. B. GREELEY, Forester, Forest Service

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INTRODUCTION

Forestry in the United States is no longer merely a theory or a subject for discussion; it has gotten down to concrete things in the woods. Nor is the growing of timber confined to public lands; it is gradually making headway on land in private ownership. It is

becoming an art of land management, expressed in practical measures for protecting forest growth from fire and other destructive agencies, for logging timber so as to produce a new crop of wood, and for planting forest trees on cut-over areas. The value of timber, along with other economic considerations, is causing landowners more and more widely to study the possibility of profitable reforestation. These developments have created a general demand for information on the timber-growing methods adapted to the various types of forest growth in the United States and on what these methods will cost.

Timber culture, like the growing of farm crops, is necessarily governed in any country by the soil and climate, by the requirements of the native forest trees, and by the national economic circumstances. Lessons may be drawn from the experience of other countries, as the United States has drawn upon the forestry practice of Europe; but profitable methods of growing timber, particularly under the wide range of forest types and economic conditions in the United States, can be evolved only from our own experience and investigation, region by region. Hence, to meet the demand for information on practical ways and means of growing timber profitably in the various parts of the United States, it is important that the results of our own experience and investigation to date be brought together and set forth in the clearest possible way.

This the Forest Service has attempted to do in a series of publications dealing with the 12 principal forest regions of the United States. The information presented has been gathered from many different sources, including the experience, as far as it was obtainable, of landowners who have engaged in reforestation. An effort has been made to bring together all that any agency has yet learned or demonstrated about the growing of timber in the United States; and the results have been verified as far as possible by consultation with the forest industries, State foresters, and forest schools. These publications thus undertake to set forth, in a simple form, what are believed to be the soundest methods of reforestation as yet developed in our common experience and study in the United States.

Necessarily, the Forest Service claims no finality for the measures proposed. Timber growing in every country has come about through a gradual evolution in industrial methods and the use of land. All too little is yet known of the best methods of growing timber under American conditions. As time goes on, research and practical experience will add greatly to the success and certainty of the measures carried out in our woods, just as American agriculture has steadily become more highly developed or just as our manufacturing processes have been perfected through experience and study. But we know enough about growing timber now, in the forest regions of the United States, to go right ahead. Believing that the forest-landowners of the United States are now ready to engage in timber growing on a large scale, the Forest Service has endeavored to place before them in concise terms the best suggestions and guides which the experience of this country to date affords.

In these publications the measures proposed for a particular forest region have been arranged in two general groups. The first includes the first steps, or the minimum measures based on local physical con-

ditions, that are needed to prevent timber-bearing land from becoming barren. These measures, in which the prevention of fire is of outstanding importance, represent broadly speaking the least that must be done and the lowest cost that must be incurred to keep forest lands reasonably productive. While influenced in some cases by the economic conditions in the region, they have been worked out primarily from the standpoint of the landowner who may not be ready to engage in real timber culture but who wishes to prevent cut-over tracts unsuitable for any purpose except timber growing from becoming a liability on his hands. Except within certain limitations, which are discussed in dealing with particular regions, the Forest Service believes that these first steps or minimum measures should be speedily applied to all of the forest lands in the United States. And the service believes that public policy should encourage their universal application in such ways as protection from fire and the adjustment of forest taxation to the business of timber growing.

The second group of proposed measures constitutes what may be called the desirable forestry practice in the region concerned as far as our knowledge and experience to date enable us to determine it. These measures are designed to grow reasonably complete crops of the more valuable timber trees, making full use of the real productive capacity of the land. The recommendations are addressed primarily to the landowner who wishes to use his property up to its full earning power for timber culture. It is impossible to frame any general set of measures of this character that are adapted to the individual needs of particular holdings or industrial establishments. This is true particularly of forest regions like the Northeastern States, which include a great variety of local situations both in the types of growth and in economic circumstances. Hence, in presenting this group of suggested measures, the Forest Service has attempted only to draw the broad outlines of the more general and fundamental things, with illustrative methods of forest practice. The details of intensive forestry, like the details of intensive agriculture or engineering, call for expert survey in working out the plans and methods best adapted to a particular tract of land or a particular business. One of the most important features of expert planning for the management of a particular forest property or for a supply of raw material for a particular forest industry is to devise, not simply woods operations that will produce full crops of timber, but also a scheme of logging that will afford a continuous yield of products desired, in order that sustained earnings may be realized or a sustained supply of raw material made available.

In some cases it is not practicable to draw a hard and fast line between the first steps that will maintain some degree of productiveness on forest land and the more intensive measures that will bring the quantity and quality of wood produced up more nearly to an ideal management. Gradations between the two general groups of measures are inevitable. The Forest Service has not attempted, therefore, to deal with the two general types of forest practice as wholly separate and distinct, but has rather endeavored to present a common-sense and practical résumé of the various steps in timber growing in the form that will be most helpful to the man in the woods. The bulletins have been written for the landowner and the

lumberman rather than for the technical forester. Their purpose is to put the main ideas into the most useful form, considering the special needs and problems of each region, for aiding the man to whom timber growing is a concrete business and logging problem. At the same time it is hoped that they will have value for the every-day reader who is interested in forestry as an important phase of land use in the United States and in the public policies designed to bring forestry about.

It is impossible for publications necessarily dealing in broad terms with the conditions existing over large regions to attempt any brass-tack conclusions on the cost and returns of timber growing. The approximate cost of the measures advocated is indicated as far as practicable, with the extent to which they may be of benefit in connection with logging operations but with no attempt to segregate the items chargeable to harvesting one crop of timber from those which should be regarded as invested in a following crop. Conservative estimates of the future yields of timber that may be expected under the various practices recommended are given where the facts available appear to warrant them; but no forecasts of the profits to be derived from commercial reforestation are attempted. The financial aspects of forestry can not be dealt with in general terms. Here again expert advice must deal with the situation and with the problems of the individual forest owner or manufacturer.

As a broad conclusion, however, with the exception of limited situations which are dealt with region by region, the Forest Service has tremendous faith in the commercial promise of timber growing to American landowners. The law of supply and demand is working steadily to create timber values which in large portions of the United States will pay fair returns on forestry as a business. The economic history of other countries which have passed through a cycle of virgin forest depletion similar to that which the United States is now traversing, points to the same inevitable conclusion. The time is fast approaching when forestry, and forestry alone, will supply the enormous quantities of wood demanded by American markets. The fundamental laws of business must in the nature of things so operate as to enable the markets of forest products to be supplied at a profit to the grower of timber. The returns already being obtained from this form of land employment at many points in the Eastern United States show plainly enough that this relationship between the value of timber and the cost of producing it is already coming about to a marked degree.

To the men who own forest-producing land in the United States or who are engaged in industries which require timber as raw material, forestry now offers a commercial opportunity. Satisfactory returns from forestry can not be promised in sweeping terms any more than returns from the manufacture of lumber or paper. But the opportunity for a profitable employment of capital and business talent in the growing of timber merits the same consideration and the same expert guidance as industrial opportunities in the conversion of timber. This applies with special force to the commercial institutions in the United States which have made large capital investments in manufacturing plants and distributing organizations, dependent for their maintenance upon a future supply of forest-grown material. It applies equally to the owners of land, in large tracts or

farm wood lots, the earning capacity of which lies solely in the growing of trees and which, without tree growth, will become either a doubtful asset or an outright liability.

The Forest Service earnestly asks the forest landowners of the United States to determine for themselves, with the same care with which they would approach any other business problem, whether timber growing does not offer a commercial opportunity which should be grasped. It commends this series of publications to them, not as a complete or authoritative scheme that can forthwith be followed with profit in their own woods, but as a starting point in utilizing the opportunities that forestry may hold out.

MEASURES NECESSARY TO KEEP FOREST LANDS PRODUCTIVE

THE CALIFORNIA PINE REGION AND FORESTS

The territory known as the California pine region includes both the east and west slopes of the Sierra Nevada Mountains, the plateaus of northeast California, and the valleys and seaward slopes of the Coast Ranges, excepting the coast redwood forests. Within this region western yellow pine (*Pinus ponderosa*) is the most widely distributed and characteristic tree; sugar pine (*P. lambertiana*), Douglas fir (*Pseudotsuga taxifolia*), white fir (*Abies concolor*), red fir (*A. magnifica*), and incense cedar (*Libocedrus decurrens*) are of great commercial importance. The yellow pine, Douglas fir, and white and red firs commonly occur in pure stands, and with the exception of red fir all possible combinations of the principle species may be found. Economically, the two pines are the most highly prized species. Incense cedar occupies a subordinate place in the forests because it is overtopped by the other trees. White fir and incense cedar are generally regarded as inferior species, and in some localities are not logged because of the low or nonexistent margin of profit on the lumber. Douglas fir is intermediate in value between the pines and white fir. Red fir, though valuable, is not extensively logged because of its present relative inaccessibility.

Disregarding noncommercial forest areas, the region contains about 13,616,000 acres of forest land, of which 3,247,000 is privately owned virgin forest, and 1,470,000 privately owned cut-over land. The present rate of cutting is about 51,000 acres yearly, nearly 80 per cent on private land. Existing logging practices leave unproductive at least 40 per cent of the private acreage cut over annually. The most pressing problem in the region is to keep private cut-over lands in productive shape. Provision is already made for keeping Government lands productive.

The important commercial timber types in the California pine region are:

(1) *Yellow pine*, consisting of stands in which the species forms 80 per cent. It forms the lower portion of the timber belt, particularly on the east slope of the Sierras, where on the broad plateaus it dominates the forest.

(2) *Yellow pine–sugar pine, mixed conifer, and yellow pine–fir.*—This group of types consists of various mixtures of three or four of

the principal species, with incense cedar as a secondary species. Most of the middle forest belt of the west slope of the Sierras is made up of this group of types.

(3) *Yellow pine–white fir.*—The characteristic mixed type of the east slope, in which sugar pine and Douglas fir are of very slight importance.

(4) *Sugar pine–fir*, consisting of sugar pine at least 20 per cent, and white fir or Douglas fir the rest of the forest. It occurs on the best lands at the upper edge of the mixed-forest belt on the west slope.

(5) *White fir, white fir–red fir, and red fir.*—This group of types, the composition of which is indicated, occupies most of the commercial timber belt above the mixed conifer belt.

(6) *Douglas fir.*—This type occurs within the general range of the mixed conifer belt in the northern portion of the region.

Other types are not now merchantable and are not discussed, such as lodgepole pine, subalpine, juniper, and digger pine–oak.

There is a wide range of climatic and soil conditions within the region, and timber types vary decidedly at times within a very short distance, so that it is difficult or even impossible to apply one method of treatment to all types.

In such types as pure yellow pine, on private lands, clear cutting is common; while in the mixed types, with a high percentage of the firs, many trees of merchantable size are left. At the same time the amount of advance reproduction[1] is generally greater in the mixed types than in the yellow pine type. Thus the tendency toward clear cutting is most pronounced where seed trees are most needed.

Certain factors determining forest practice, notably the effect of slash fires, are common to all types; others, particularly abundance and distribution of potential seed trees, vary decidedly from type to type. In discussing methods of timber growing, types will be treated separately when such distinction is essential to a clear understanding of the situation.

THE RÔLE OF ADVANCE REPRODUCTION AND SEED TREES

In the virgin forest, particularly in pure yellow pine, when a good crop of seed is produced (and this only occurs at intervals of from five to eight years), the chances are slight that an equally good crop of seedlings will result. The long dry season and the severe frosts typical of the region will destroy the vast majority of the young seedlings during the first years of their lives. Only once in every 10 to 25 years, on the average, does a satisfactory stand of seedlings become established.

On cut-over lands, with fewer seed trees than in the virgin forest, new young growth will necessarily come in slowly, and it must be anticipated that stands of seedlings from the seed trees left after logging will be scattered. Seed of yellow pine is not stored in the duff, and reproduction can not be obtained from that source after logging, as it is in the Douglas fir and western white pine regions.

[1] Advance reproduction refers to the young trees growing under the old timber in virgin forests. Since systematic fire protection has been given our forests, this young growth has come in abundantly. It utilizes the space freed by the death of many old trees destroyed by fire, insects, or disease.

Detailed study on old cutting areas[2] shows beyond doubt that advance reproduction must be the mainstay of the new stand throughout the region and particularly in the east side yellow pine type (fig. 1).

In all of the older cut-over areas examined, age counts made on seedlings showed that, except in rare cases, what appeared to be young seedlings that had come up after logging were in actuality advance reproduction. The casual observer, judging only by general appearance, frequently has a false idea of the ease of obtaining reproduction, particularly in pure yellow pine on the east side, simply

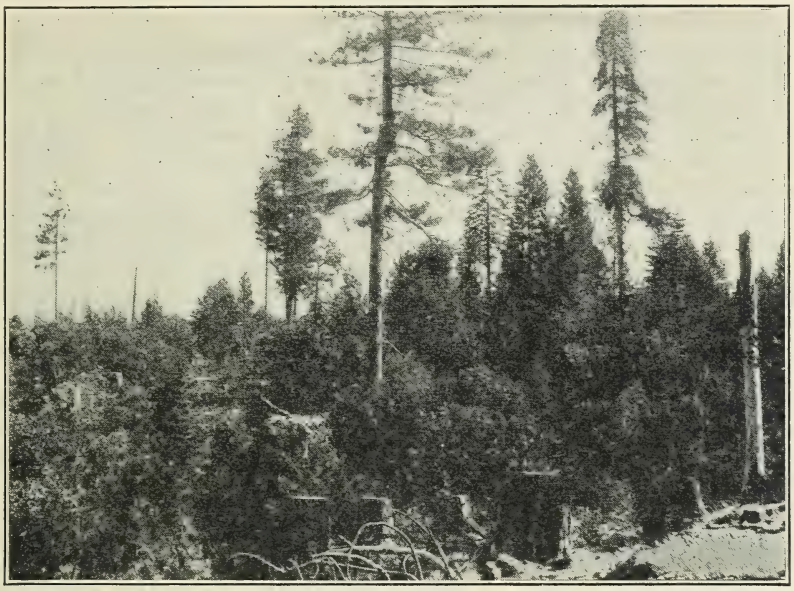

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FIG. 1.—PRESERVATION OF YOUNG GROWTH IS THE KEY TO GROWING TIMBER

In the California pine region the young trees remaining grow rapidly after the timber is cut, and represent substantial progress toward a new timber crop. They are important to the owner, whether he plans to sell or to hold his land.

through failure to realize that the small seedlings on cut-over areas are advance, not subsequent, reproduction.

[2] Practically every important lumbering operation in the California pine region, old and new, was studied on the ground, and the statements of fact in the following pages are based on these studies. A reasonably complete and balanced picture was obtained of past and present methods of logging, cutting, slash disposal, and fire protection as they affect the productivity of forest lands. The method was first to make a general survey of the entire area under observation to determine the timber types involved, type of logging used, methods of slash disposal employed, etc., then to make detail cruise strips on typical selected areas in order to have definite information on which to base conclusions.

Many of the silvical facts regarding the life history of trees and stands have already been proved. Additional field research has been done when basic information was needed, as for example on the minimum size of trees that bear seed in adequate amount. In addition, original data of the Forest Service bearing on condition of cut-over lands, and resulting from timber cruises, have been utilized.

The cost figures used in this bulletin are in all cases based on actual studies. In the few years since most of these studies were made, operating costs have increased so that probably the actual values should be raised somewhat. On the other hand, the credit items have also increased and it is believed that on a percentage basis of total cost the figures used are reasonably reliable.

The writer is indebted to Duncan Dunning, associate silviculturist, for assistance in the field study of cut-over areas and in the analysis of material.

On a cutting area in the east side yellow pine, which has been under observation for 14 years, practically no progress has been made in obtaining new reproduction. Studies of reproduction on permanent sample plots in California representative of the important types are summarized by Dunning (*7*)[3] thus:

> One of the most important results of these studies has been to emphasize the great importance of advance reproduction. It becomes more and more evident that the establishment of reproduction after cutting is a long, tedious process, requiring as high as 20 years or more on poorer sites to secure even a fair stand. In none of the sample plots even on the best sites has more than one-third of the seedlings now present been established since cutting, and in only two cases are the number and distribution of seedlings sufficient to constitute complete stocking 10 years after logging.

This applies to conservative cuttings on national forests. The conclusion is unavoidable that, in the main, the preservation of young growth throughout the logging operation, in slash disposal, etc., is the principal means of keeping forest lands productive. This fact must influence particularly the methods of logging used and the intensity and nature of fire protection measures.

Advance reproduction is, however, generally more or less patchy or scattered, and it is therefore necessary to provide for additional young growth after logging. This can be accomplished by reserving small trees of merchantable size to serve as seeders and gradually to restock cut-over areas not already sufficiently productive. Seed trees are also required in case fire after logging should wipe out the advance growth.

Similar conclusions regarding the importance of advance growth and seed trees have been reached in other portions of the western yellow pine region, notably in the Southwest and in eastern Oregon (*11*, *15*).

PROBLEMS OF THE TIMBER OWNER

The owner of forest lands in the California pine region who is engaged in the business of producing lumber faces the following definite facts:

(1) Logging must be done at a profit.

(2) Whether he desires it or not, the landowner is in the cut-over land business on an increasingly large scale.

(3) Cut-over lands are generally of value primarily for timber growing. The demand for cut-over land for grazing, agriculture, and recreation is exceedingly local and small.

(4) The value of cut-over land to the owner (beyond a nominal value of bare land) therefore depends on the amount and character of young growth and seed trees remaining after logging. This is equally true whether the land is held and managed as part of his own going operation, or whether it be sold to some one who will manage it for timber production. Such purchasers as may exist can pick and choose, because of the already large area of cut-over land. They will not pay and can not be expected to pay for values (young growth and seed trees) which do not exist (*2*).

(5) Existing methods of exploitation do not generally leave cut-over lands productive (fig. 2).

[3] Italic numbers in parentheses refer to "Literature cited," p. 75.

(6) To keep going an existing operation, with a heavy investment in plant, transportation, and equipment and with established markets, a new crop of timber must be grown on the lands now being logged. The condition of cut-over lands is then equally important whether this grower of forests is the private owner or the public, for the physical things necessary to produce a forest are identical in either case. The permanence of the operator's timber supply depends largely on whether he adopts steps that will produce timber crops on his cut-over land. No mere shift in ownership of land can possibly offset the long-continued effects of destructive lumbering.

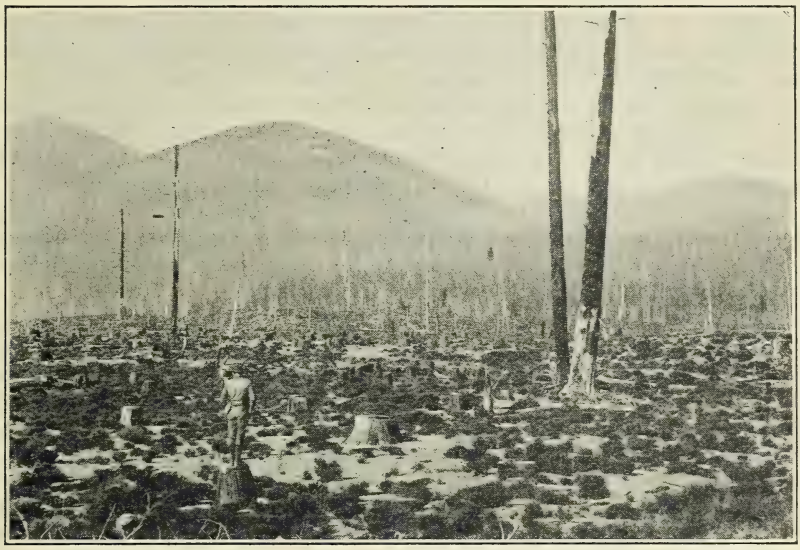

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FIG. 2.—DESTRUCTION OF YOUNG GROWTH TURNS FOREST INTO WASTE LAND

Only a single severe summer fire in the slash left from logging was needed to reduce this forest land to an unproductive waste one step removed from desert. Centuries will perhaps be required to reestablish a complete forest cover by natural means.

(7) The public has declared its interest in the fate of cut-over lands by substantial contributions of cash for protection against fire, and obviously expects similar action from timber owners.

These make the real "economic problems" that confront the forest owner. They overshadow the commonly recognized and highly important tax and carrying charge questions, and any businesslike consideration of the future of his timber operations must start with them.

Thus the owner of forest land in considering the first steps in growing timber as an integral part of his business, requires answers to several definite and practical questions:

What steps in logging, slash disposal, and fire protection are essential to leaving cut-over lands reasonably productive?

Are these steps practical, and what is their cost above the usual measures now taken on private lands?

What returns can be expected in growth of timber if these steps are taken?

In working out the answers to these questions two different groups of controlling factors must constantly be kept in mind and balanced one against the other. These are, on the one hand, the life history of the forest itself, particularly its manner of reproduction; on the other hand, the process of exploitation and subsequent care and treatment of cut-over lands. It is hopeless to violate the intrinsic needs of the forest and expect the forest to continue; it is equally hopeless to propose desirable but unduly costly and impracticable methods of logging, slash disposal, or fire protection, and expect them to be followed by a strongly competitive industry.

To talk of planting as a remedy for destructive logging is to beg the question. Because of high cost (not less than $12 to $15 an acre), difficulty of the operation, particularly on stony ground, uncertainty of success owing to imperfectly established methods, and lack of forest nurseries, planting is a last resort. It is likely to be employed only where natural reproduction fails. The opportunity for timber growing in the California pine region lies primarily in saving what is already in existence. The young growth and seed trees already on the ground represent the only real basis for a new forest. The simple steps necessary to leave cut-over land productive must be taken as part of the logging operation.

In discussing the problem of the operator who wishes to maintain the productivity of his timberland, it is necessary to consider not only the practical questions now confronting him but also the causes which have brought about the existing situation. Throughout its history the lumber industry has treated forest land as a mine from which to remove valuable accumulations rather than as a possible source of successive wood crops. This practice has resulted naturally from the enormous reservoirs of virgin stumpage available and from the highly competitive nature of the business, which have forced rapid and cheap exploitation.

As a consequence of the urge for production and of the general indifference to the fate of cut-over lands, three major factors of denudation of forest land have come into existence in California. These are fire, methods of logging, and intensity of cutting. A fourth factor, overgrazing or unregulated grazing, is also of occasional importance.

Broadcast burning of slash and uncontrolled fires on cut-over lands have certainly been responsible for a large share of the denudation in the past, and this factor has been recognized and discussed almost to the exclusion of methods of logging and closeness of cutting. In late years, however, the high lead and high speed methods of power logging, and clear cutting in pure pine types, have come to be recognized as belonging definitely in the class of major factors of denudation.

These three factors must be considered by the logging operator who wishes to maintain the productivity of his timberland, and who is therefore interested in determining, (1) the cause of losses in productivity now taking place and, (2) the means of reducing or eliminating such losses without serious disruption of existing practices or serious additional cost.

FIRE PROTECTION AND SLASH DISPOSAL

THE GENERAL PROTECTIVE SYSTEM

The general protective system applying to all forest lands should be intensive enough to prevent serious damage to merchantable timber or advance reproduction. Success in growing timber demands that the average yearly burned area shall not exceed one-fifth of 1 per cent of the entire forest area. This rate of loss will not seriously reduce the productive area of a forest property in the 75 to 100 years required to produce a new timber crop. On the other hand, a figure even approaching the present 2 per cent to 3 per cent of cut-over lands burned annually will so greatly cut into the timber growth and leave so much land with no commercial forest that profitable management becomes impossible. Systematic fire protection before, during, and after logging is thus a measure of prime importance.

Since preservation of advance reproduction is so important in continuing the stand, it follows that broadcast burning of the virgin forests should be avoided, because even light surface fires destroy most if not all of the young growth. Light or controlled burning has been found a futile and costly expedient for reducing hazard in the forest *(14)*. The practice is difficult to carry out, involves material sacrifices of both mature timber and reproduction, and thus leads to the very sort of loss it seeks to prevent. The insignificant reduction of hazard accomplished by light burning is soon more than offset by increase of inflammable material created by burning. Therefore "light burning" has no place in even the crudest attempt at timber growing.

Wherever fire occurs in virgin forests the minimum damage is the serious reduction of the advance reproduction and the burning down of occasional mature trees.

Years of experience of the Forest Service show that with large and somewhat broken holdings an annual expenditure of 1.5 to 2.5 cents per acre per year for an organization[4] for suppression of fires will result in less than 1 per cent per year burned over. Most timber owners buy protection of their lands from the Forest Service at the rates applicable to national forest lands. This expenditure is, however, inadequate, to guarantee protection on compact holdings of a few thousand acres. Some owners recognize this and insist on more intensive protection. Also as timber becomes more valuable the scale of protection will inevitably be raised.

For adequate protection on the smaller or more compact holdings a general average expenditure of at least 3 to 4 cents per acre per year will be needed, using the type of organization developed on the national forests. This includes the retiring of investment in telephone, trails, and other protection improvement, wages of fire guards, and suppression costs. It provides, in the virgin forest, one-hour control, or an organization capable of putting suppression forces on a fire within one hour after its start. On cut-over lands the general protective system should provide half-hour control, at an average yearly cost of 6 to 8 cents an acre.

[4] A standard fire-control system provides for systematic detection of fires, for rapid transmission of messages concerning location of fires, for dispatchers to initiate action, and for guards to start suppression work, together with the necessary tools, equipment, means of transport, and roads and trails.

SLASH DISPOSAL

On cut-over lands, two factors account for a set of problems that do not exist in the virgin forest and that require a more specialized system of protection. These are slash disposal and the logging operation itself as a source of fires.

The large quantity of slash from the trees that have been cut, added to the advance reproduction and brush present before logging, gives cut-over areas in any type possibilities of fires far more intense, more damaging, and more difficult to combat than in the virgin forest. One of the prime necessities in fire protection is thus reduction of the slash hazard, and the breaking of cut-over areas into blocks so that control of fires may be assured. Several methods of slash disposal are already in use in the pine region.

BROADCAST BURNING

In the past, it has been a common practice on private lands to burn the slash broadcast, which simply means touching it off as it lies after the logs have been removed, and stopping the resulting fire when it reaches virgin timber. Frequently, too, fires starting during logging, generally from the operations themselves, have been allowed to burn, with essentially the same effect as fires deliberately set. An example of the maximum destructiveness of broadcast summer burning of slash was encountered on private land in the yellow pine type on the east side of the Sierras, logged in 1914 and burned over the following year. The slash, to be sure, was completely consumed, but the considerable quantity of advance reproduction and a number of seed trees that had survived logging were completely wiped out. A strip run on this area showed in 1½ miles just two seedlings and no live seed trees. The brush which is now in possession of the ground is a species indicative of a nontimber site, showing that besides destroying the young growth the fire ruined the soil itself, leaving it incapable of sustaining forest trees for many years to come.

Many cases were found in which part of a cutting area had been broadcast burned while part had escaped fire. The result of such treatment is the wiping out of the new forest on burned ground, and the occupation of the land by worthless brush. In contrast, particularly on older cuttings, the unburned lands generally are in fair shape, with advance reproduction and seed trees. Slash fires usually wipe out not only the smaller reproduction but seed trees as well, so that the return of the forest is a matter of decades.

The minimum effect of slash fires is the destruction of advance reproduction and the death of some seed trees. Such fires, however, do not completely consume the slash, and the fire hazard, which the burn aims to reduce, remains but little lower than if the slash were left untouched. The rapid invasion of the brush is also aided by broadcast burning (fig. 3).

Even where only minimum damage results on part of a slash burn, it is not uncommon to find complete destruction on another portion of the same area. Extensive fires are so uncertain in their action that it is impossible to control their effect on the forest.

One company has recently experimented with summer broadcast burning of slash on relatively small areas of 5 to 25 acres surrounded by fire lines, on the theory that the fires would not be destructive if they did not become extensive. Study on the ground makes it clear that this, like other forms of broadcast slash burning in the yellow pine type, is disastrous in its effect on the forest. A sample strip on this area showed the following effect of summer slash fires on advance reproduction:

Number of seedlings per acre before fire	705
Number of seedlings per acre after fire	86
Percentage of reproduction left	12
Percentage of plots with reproduction, before fire	80
Percentage of plots with reproduction, after fire	31

F-156377

FIG. 3.—BROADCAST BURNING OF SLASH CREATES BRUSHFIELDS

Slash fires not only destroy the advance reproduction, but commonly kill many seed trees as well, leaving the land to the vigorous invasion of valueless brush species.

Extreme care was taken on this area to prevent the spread of fire to virgin timber, and as a matter of fact, the cost per acre was as great as if the slash had been gathered into piles and burned. Nevertheless, the advance reproduction was nearly wiped out, as illustrated in Figures 4 and 5, and this, coupled with the clear cutting, makes the future productivity of the area very doubtful.

The uncertain action of fire is illustrated by another instance, where a splendid stand of nearly pure yellow pine has followed cutting and broadcast slash burning in the mixed conifer type on a north slope. This is one of the unusual cases resulting from a rare combination of factors—good seed crop ripened before logging, fire removing competing vegetation the same season as logging, and favorable subsequent seasons. That such special conditions can not be relied on is shown by the adjacent south slope, where the same fire resulted in denudation. Several other areas showing favorable

results following broadcast slash burning were found in various parts of the State, but as a percentage of the total number of areas examined they were negligible.

In a wide variety of forms, with spring, summer, and fall burning, on every important type, and in the great majority of cases, broadcast burning results in leaving the land unproductive. It is only under very special conditions that broadcast burns restock completely to desirable species, regardless of the intensity of the fire. Where occasionally the damage is confined to destruction of advance reproduction and small trees, the slash is not completely consumed and fire hazard remains high. As already noted, a further disadvantage of broadcast burning is that the spread of brush is much more rapid on burned than on unburned areas logged at the same time. Clearly the method can not be used if continuous forest production is sought.

PILING AND BURNING

Slash may be disposed of by first piling it so that it will cover a relatively small portion of the area and then burning it, as is done generally on national forest cuttings. This method is effective for reducing fire hazard but is rather expensive. A more detailed discussion of this method will be found in the second section of the bulletin.

Where the object of the owner is simply to leave cut-over lands reasonably productive, it is not certain that piling and burning is necessary. Partial disposal of slash must first be examined as an alternative.

PARTIAL DISPOSAL OF SLASH

By piling and burning the débris on strips, and leaving the slash elsewhere, the essentials of low cost of disposal and safety of cut-over lands may be attained. In an extensive examination of cut-over lands two impressive findings were the very considerable proportion of cut-over lands that escape fire with no slash disposal or protection whatever, and the rapidity with which slash on such areas disappears. This statement is not an indorsement of a laissez-faire policy for cut-over lands, but serves to indicate that a study of areas untouched by fire is just as necessary as is an examination of burned lands.

The desirability and practicability of leaving part of the slash must be considered from at least three angles:

(1) Most important, what can be expected in protection of lands on which slash is left, and how rapidly and completely will this slash disappear?

(2) What influence will leaving of slash have on development of advance reproduction, and how will it affect the chances of obtaining new reproduction?

(3) Does undisposed-of slash constitute a menace as a possible starting place for epidemics of destructive insects or fungi?

The last question can be answered with a reasonable degree of certainty. The danger of serious insect epidemics starting in slash appears to be slight. Freshly cut stumps and slash are of course breeding place for such insects, but the broods normally go from

stump to stump and from slash to slash, rather than from stump or slash to standing tree. It is difficult to see how any form of slash disposal, even piling and burning, could prevent attack of standing

F-160194

FIG. 4.—ADVANCE REPRODUCTION BEFORE BROADCAST SLASH BURNING

This reproduction is the result of fire protection, and means that the new crop of timber is by so many years nearer maturity.

F-161208

FIG. 5.—SEED TREES KILLED AND REPRODUCTION WIPED OUT

The same view as Figure 4, after broadcast slash burning, tells the story of a practice that has made many thousands of acres in the California pine region unproductive, a loss to the owner, the State, and the Nation.

trees by insects. Many stumps are not affected by slash fires nor are they peeled, and since slash is burned in the fall and not currently at least one generation of insects would have a chance to breed in

stumps or in slash before the slash is burned. So far as insects or fungous attacks are concerned, slash may be left on the ground. Bark beetles as a rule avoid limbs and small tops which may dry out before the brood matures. The danger to living trees from fungi which destroy slash is slight.

Studies under way will at some future time make it possible to define the effect on subsequent reproduction of leaving slash. Even now it is fairly certain that no pronounced trouble is due to leaving slash; and in some cases, especially in yellow pine, there is evidence that the slash is an actual aid in establishing reproduction. Some advance reproduction is, of course, bent over by undisposed-of slash, but at the worst this is only a small percentage of the total left after logging, and it is safe to say that loss from this source is no greater than that from piling and burning.

The question of leaving slash then resolves itself into a study of the fire hazard, the possibility of controlling fires, the rapidity with which slash disappears naturally, the possibility of preventing fires starting, and the suppression while small of those fires that do start.

In a field study of many cut-over areas of ages varying up to 47 years, the examiners noted in all cases the degree of decomposition of the slash in relation to the length of time since cutting. The period required for slash to disappear entirely is rather long, probably 20 to 25 years, but it was found that after the needles and twigs were gone, the remainder, consisting of the larger limbs, pieces of the main stem, etc., did not seriously increase the difficulty of control or the damage caused by fires. Because of the heavy snowfall in the California pine region, piles or windrows of slash are mashed down rapidly; after the needles drop, usually the second year after logging, the whole mass is flat on the ground and decomposition fairly rapid. Where slash is flattened fires are not so intense or difficult to control as in fresh slash, since the whole mass can not catch simultaneously as it does when propped up in the air.

In the majority of cases it was found that, in a period of 8 to 12 years after cutting, the slash had ceased to be a special hazard. Exceptional areas varied from 5 to 15 years, and even on cuttings of 30 years or more some of the larger limbs and sections of the trunk remained. As a general working rule, however, within 10 years after cutting decay and compacting so reduce slash that special protection is unnecessary on this account alone.

The argument for slash disposal rests on the well-proved fact that fires in fresh slash are very difficult to control and are extremely damaging to the remaining stand of timber. The argument for leaving slash in whole or in part is based on the facts that it ceases to be a menace in fire protection in the course of a comparatively few years, that any form of disposal unless carefully done causes material damage to the remaining stand, and that the money necessary to dispose of slash properly would provide for intensive protection of the cut-over areas. Such protection will be necessary even if slash is burned.

Final decision as to the best method of slash disposal must wait upon an examination of fire-protection possibilities on cut-over lands. Leaving most of the slash and maintaining an intensive patrol is a possibility.

Clearly, if most of the slash is left, and will lie for about 10 years before hazard is reduced to normal, some special protection must be provided during that period. Special patrol of danger areas, in addition to the general fire protection measures, is of demonstrated value in protecting cut-over land.

OTHER METHODS OF SLASH DISPOSAL

Foresters generally are agreed that no method of slash disposal now followed is necessarily the final word; and a wide variety of methods have been proposed for getting rid of the slash with the minimum damage to reproduction and seed trees and at a low cost per thousand feet of logs.

Lowdermilk, in the white pine region of Idaho, has made preliminary investigations to determine the feasibility of other methods than piling and burning (*9*), and work of a similar nature has been done elsewhere. Under certain conditions such methods as swamper burning and spot firing of slash as it lies have proved successful and cheap. Spot firing on at least one area in Montana in a yellow pine–larch–Douglas fir type gave fine results; but where it has been tried in the yellow pine type in California, the result was destructive of advance reproduction, for the slash was thrown in with the reproduction in swamping and in clearing wheel roads. None of the various methods for current disposal of slash seem to have proved its general applicability, though there are undoubtedly great possibilities in that direction.

Several methods designed to hasten natural breaking down of slash have been tried, especially in the Southwest (*11*). Lopping and scattering, pulling tops away from seed trees, and lopping without scattering have produced results that may be valuable under certain conditions. The hazard on cut-over lands existing immediately after logging is not reduced materially by any of these methods, however, and at most they hasten the decay of slash by only a few years.

One large company in California has recently tried lopping and scattering slash. Previously the company had piled and burned slash on its own lands at an average cost of 36.6 cents a thousand board feet of lumber cut, but was not satisfied with the results because of the difficulties in burning piled slash without serious damage to advance reproduction. The cost of lopping and scattering was 3.9 cents a thousand, or, plus charges for clearing around camps and donkeys and for supervision and patrol, 7.6 cents a thousand. The suppression costs were $317 for the season. The company is well satisfied with the method so far, both from the financial and forest conservation points of view.

Disposal of slash is an integral part of the problem of fire protection of cut-over lands. Until experimental work shall have gone further than it has now, it seems fair to conclude that if complete disposal of slash is considered essential, piling and burning is the method that should be depended on since it accomplishes the maximum in reducing hazard. But because, as is shown in the detailed description of this method in the later part of the bulletin, special protection is needed even after piling and burning, and because of the cost of the practice, a less expensive means of slash disposal is

desirable. Leaving most of the slash, plus intensive patrol, meets these conditions.

If the slash is piled and burned on strips along the railroads and roads, and on additional strips to break the area into blocks of 40 to 80 acres, usually not over 20 per cent of the total cut-over area need be treated. Such a system of partial disposal of slash goes far in reducing the danger of slash fires, and the cost is low.

THE NEED FOR SYSTEMATIC PROTECTION OF CUT-OVER LANDS

Although the best methods of protecting cut-over lands are not yet fully worked out, it is easy to show that special measures must be taken. As an example of what happens under a laissez-faire policy, the cumulative results on one large operation over a period of 20 years (*1*) show that on 16.7 per cent of the total area the stocking, or the degree to which the young growth approaches the full amount of wood that the land can grow, was 60 per cent or better, averaging 72 per cent. On 52.4 per cent of the area the stocking was 10 to 60 per cent complete, averaging 28.5 per cent; and on 30.9 per cent the stocking was 0 per cent.

If these generalized figures be plotted and a curve drawn, the percentages appear as in Table 1.

TABLE 1.—*Relation of area to stocking on a percentage basis, on unprotected cut-over land*

Area	Stocking	Area	Stocking	Area	Stocking
Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
31.0	10 or less	7.0	41 to 50	4.0	71 to 80
19.5	11 to 20	5.0	51 to 60	4.0	81 to 90
12.5	21 to 30	5.0	61 to 70	3.0	Over 90
9.0	31 to 40				

Although only 31 per cent is completely stripped of young growth, half the area is less than one-fifth stocked and about two-thirds is less than one-third stocked. This deficiency is largely owing to slash fires. The result of neglect of cut-over lands is quite as likely to be a forest partly stocked, patchy, and damaged by fire and disease as it is to be absolute and complete denudation. Not only does the area of cut-over lands that are denuded reach an impressive total, but the fact that hundreds of thousands of acres are producing wood at only a fraction of their potential rate is of at least equal concern.

The condition of this typical area demonstrates the imperative need of a specific program for fire control on cut-over lands.

QUESTIONS INVOLVED

Protection from fire is the most important single requirement to maintain cut-over lands in a productive condition. Neither high lead logging nor clear cutting, destructive as these practices will be shown to be, results in completely wiping out timber growth on large areas. Uncontrolled fires do just that, and in addition make it impossible for the forest to return for decades or in some cases centuries.

The problem of protecting cut-over lands involves study of three principal questions:

(1) What are the causes of the fires, and what can be done to eliminate these causes and prevent fires from starting?

(2) Can fires on cut-over lands be controlled after they start, and what can be done to prevent large uncontrolled fires?

(3) With the foregoing questions answered, what form and method of protection will deliver satisfactory results?

CAUSES OF FIRES

Only a few of the fires that start on cut-over lands in California are ever reported, and detailed study of the causes of fires is therefore difficult. Of an average of 1,050 fires each year handled by the Forest Service in the 12 heavily timbered national forests in California, only 56 are reported as due to logging, and of these only 13, or 23 per cent, are reported as fires of over 10 acres in size. This is certainly a very incomplete record of logging fires. Taken at face value it indicates that logging operations are a very minor factor of risk, whereas experience and study of operations prove beyond question that prevention and suppression of logging fires is the main problem in protecting cut-over lands. Until recently no record of logging fires on private land has been kept by any of the important lumber companies, so that the very meager data now available can at best serve only as an indication of the actual situation.

One of the larger companies, which in 1922 made a serious effort to reduce and control fires on its own lands, has the following record of fires for one year by causes:

Logging railroad engines	144
Donkey engines	32
Miscellaneous	10
Total fires	186

Both the railroad and the donkey engines are wood burners, and the great number of fires started by them in spite of the use of spark arresters shows clearly the high risk (or likelihood of fires starting) owing to the logging operations themselves. The miscellaneous fires include a few fires that escaped in cleaning along rights of way, a couple of lightning fires, and a camper fire. If these data are representative, as they are believed to be, they show beyond question that the principal risk on recently cut-over areas is from the logging operations. As a corollary of this, it is obvious that the risk areas are first, narrow strips along operating railroads; second, narrow belts around donkey settings; third, and probably less important, highways through cut-over land which are used by the general public. Undoubtedly, too, some slash fires start from smoking in the woods by employees of lumber companies, and from fires started for warmth and left unextinguished.

These considerations lead to the further conclusion that once an operation has gone from a particular cut-over area and logging railroads no longer touch it, the risk is reduced to the normal or blanket risk for that region, from occasional lightning, smoking, or camper fires. Experience indicates that such is the case. The great

majority of accidental slash fires start the year of logging or the year after.

PREVENTION OF FIRES

The problem of successful protection of cut-over lands is to prevent fires from starting, or if they do start, to have the special-risk areas in such condition that fires can be quickly controlled, and to have ready the specific organization to control them.

Fires may be prevented from starting by either one of two methods: (1) By using such fuels and mechanical devices as will insure that sparks do not reach the ground; (2) By so clearing the ground where sparks will fall as to leave insufficient inflammable material to carry fire.

Several practical and workable methods for preventing fires are in use on the national forests and to a lesser extent on private cuttings. These are:

The use of oil instead of wood-burning railroad engines.—Oil-burners sometimes set fires, but very much less frequently than wood-burners.

The clearance of strips along operating railroads.—The exact technique may vary, but in general strips averaging 100 feet each side of the right of way are cleared, either by broadcast burning from fire lines at the outer edges of the strip or by piling and burning slash. Sparks falling on such ground seldom set fires, because of lack of material. This method has been used with conspicuous success by one large company in the southern Sierras.

Clearing around donkey settings in advance of yarding.—This ordinarily involves using a small crew continuously, to put a fire line around the area, and broadcast burn toward the center. This method has been used successfully by several companies and has practically eliminated serious fires starting from donkey engines.

The use of spark arresters with wood-burning engines.—There is no thoroughly satisfactory arrester in use, but even the ones now available are an important factor in preventing fires. Inspection of the engines on logging operations shows great laxness in the use of arresters.

Care in the use of fire in the woods by employees.—Fires caused by logging employees can be absolutely stopped if camp bosses and woods foremen really want to stop them. Some companies now refuse to sell ready-made cigarettes to employees because of the danger that fires may be set by them. Prohibition of smoking by employees, except at camps and designated safe places, has already been successfully used as a fire prevention measure.

Control of use of lands by campers, hunters, and fishermen.—Fires caused by campers, hunters, and fishermen are by no means uncommon, though generally of less consequence than fires from logging. The application of a camp-fire permit system to private as well as national forest lands would aid greatly in reducing fire losses of young growth.

PROMPT SUPPRESSION OF FIRES

So much for prevention measures. In attempting to define methods of fire suppression, or of preventing the spread of fires already started, it is safe to go on the basis of what actually has been and

is being done. The principal fire suppression measures that have proved successful are:

A properly equipped patrol following trains.—In the case of one company, 144 fires due to railroad engines started along parts of the right of way where clearing had not been done. Part of this was in slash, part in virgin timber. Patrols after the train confined all these fires to small areas. Other companies use the same method, usually more or less spasmodically, though it must be obvious that continuity is the essential if disastrous fires are to be avoided.

The equipment of donkey engines with pumps, hose, and fire-fighting tools.—On national forest cuttings where this is made a contract requirement, serious fires starting from donkey engines have been greatly reduced. Fire-fighting equipment at machines should be kept in a special place and used only for fires. There is a serious danger that shovels and axes will become scattered on the logging job and will not be available when needed.[5]

Placing responsibility for initiating action on fires.—On all but the smaller operations, a camp fire warden is advisable. He should be commissioned as a deputy State fire warden, and should be given responsibility for organizing the camps for fire control, teaching the men their duties on fires, enforcing regulations about smoking in the woods, care of spark arresters, dumping hot ashes, building bonfires, etc. He should be a man of intelligence and energy and be accustomed to handling men. He should be specifically charged with fire control activities on all risk areas and be free of other duties. In addition, some individual in each risk area should be designated to start action. At donkey engines this may be the engineer of fireman; in the woods, the hooktender; along railroads, the patrolman, etc. The characteristic of logging fires from all causes is the long delay in attack owing to failure to fix responsibility for starting action. Practically all such fires occur where plenty of men and tools are available to put them out, but the tendency has been to take a chance that they will go out of themselves, which they seldom do.

ADDITIONAL MEASURES

It is too much to expect that this generally adequate plan of special fire control will catch all fires while small. Human fallibility is ever a factor, as experience demonstrates; and, despite all care, occasional extreme winds will result in large fires. What can reasonably be done to reduce to a minimum the danger of a conflagration? Certain possibilities are fairly obvious, and are already in use on some operations:

To fall snags on cleared strips along the lines of special risk.—Particularly on cut-over lands snags are a great potential danger, since sparks fly from them for long distances and set fire in advance of the main fire.

At the outer edge of cleared strips to maintain a fire line cleaned to mineral soil and of sufficient width, usually a few feet, to stop fires that may be unattended for a time.

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[5] Portable gasoline pumps have proved their value in controlling fires starting from donkey engines. They are particularly useful in extinguishing burning chunks, snags, and logs, and thus making a prolonged patrol unnecessary.

To block out large, compact areas with fire lines.—The greatest danger is that fires will get a good start in the major portion of the cut-over areas outside cleared strips. Even piling and burning of all slash will not, in such cases, prevent rapid spread and great destruction. The logical precautionary measure is to break up the cut-over area into blocks by supplementary cleared lines, on which all slash is piled and burned, and from which back-firing can be done at short notice. Such lines can not be expected to stop bad fires automatically, but will give a good place from which to fight them. The size and shape of blocks will necessarily vary, since location of the lines will naturally take advantage of topography features, existing roads and trails, etc. Blocks should not exceed 80 to 100 acres in size and preferably should be smaller. The basic idea of blocking is, of course, to confine bad fires to a single block, and it must be expected that if a fire gets a good start on a cut-over area, either in slash or where slash has been burned, it will burn out an entire block.

THE ESSENTIAL STEPS IN FIRE CONTROL

The special measures suggested for prevention and suppression are, it is worth emphasizing, obvious and common-sense steps, as necessary for protection of the operation as to save young growth. If experience in logging California pine demonstrates anything, it is this: Fires will start, they will become large unless tended, and the operator responsible sooner or later has a large and costly suppression job on his hands, with consequent serious interruption of logging and possible loss of valuable equipment, improvements, or timber. The experience of the few operators who have really attacked the problem of reducing these big suppression jobs to a minimum corroborates that of the Forest Service, and shows that fires due to logging can be controlled consistently and at small cost, but that this control must be made a specific and carefully planned project and not considered an incident to logging such as can be attended to by anyone.

To sum up, the few simple and inexpensive steps needed in addition to the general protection system which should apply to all forest lands, virgin as well as cut-over, include clearing of the ground around special risk areas, breaking of slashings into small blocks by cleared lines, and use of mechanical devices and fuel that will prevent sparks from reaching the ground. They include also employment of a camp warden system and the designation of specific individuals to handle suppression in each area of special risk. Equipment necessary for suppression must of course be provided; snags on special risk areas should be felled, and a special patrol provided during and after logging until the hazard is reduced to normal.

THE COST OF SPECIAL FIRE PROTECTION MEASURES

The direct costs of the various steps proposed as special fire protection measures on cut-over land are well established by the experience of private owners as well as that of the Federal Govern-

ment. These costs per thousand board feet of the cut, not including overhead, may be summarized as follows:

Clearings and disposal of slash on lines	$0.10 to $0.12
Clearing around donkey settings	.02 to .03
Falling snags on special risk areas	.02 to .03
Special patrol during and after logging for average period of 10 years, at 6 to 7 cents per acre per year	.03 to .05
General protection measures	.02 to .03
Total	.19 to .26

The actual expense for the first and second items combined for one company in 1921 was 9 cents per thousand.

Now whether the actual cost is 19 or 26 or 30 cents, the assumption is likely to be made that it is an extra cost, one which simply represents money spent with no return. But a more careful examination indicates that there is another side to the story.

As a matter of general experience and of record, large areas of cut-over lands are burned each year. Practically every slash fire must be fought sooner or later, and usually by the operator. Logging engines in the woods are threatened, standing private timber must be protected, or the fire is likely to reach national forest land, with consequent liability of the company for the damage caused. Unfortunately, operators generally have not kept track of the cost of fighting fires due to their own operations, but there is no question that every large company is compelled by force of circumstances to expend considerable sums in fire suppression. Almost invariably this means shutting down a donkey or an entire camp, and in some cases mill crews must be put on the fire line as well. Aside from the actual wage cost, and the occasional loss of expensive equipment, the interruption of logging operations is a real loss.

In 1919 and 1920 one company spent an average of nearly $10,000 a year on its cut-over lands for suppression of fires resulting from its own operations. In 1921 it started clearing along rights of way, with patrol following all trains, and its suppression bill dropped to less than $1,000 and total fire cost, including prevention, to $3,600. To estimate the entire expense of the partial slash disposal plan, which must be far less than the former losses, it remains only to be seen how frequently the strips must be recleared in order to make protection certain.

So, against the estimated 19 to 26 cents per thousand that it is proposed to spend for prevention, there must be balanced the cost of fighting serious fires plus loss of equipment and merchantable stumpage. What these items amount to on the average is not known. The large company above-mentioned found that its expenditure for fire suppression alone for the years 1919 and 1920 was 21 cents per thousand.

Regardless of the effect of fire protection on cut-over lands, systematic protection along the lines advocated here will pay surely in the saving in suppression costs on large fires. Progressive companies have proved this to their own satisfaction.

The experience of the Forest Service demonstrates that intensive protection, with a force of men sufficient to catch fires while small, is more economical than a scattered protection force plus frequent expense on large fires.

Even if we assume the obviously extreme position that all expenditures for protection are a net operating charge, a little consideration will show that the situation is not altogether hopeless from the operator's point of view. Either he is going to hold his lands for forest purposes or he is going to sell them to someone else who will use them for forest production. If he holds them, he has a start of a new crop instead of partly denuded and worthless land. If he sells them, the market value of productive lands is inevitably going to be higher than that of denuded lands, whether or not that extra value is formally recognized by the purchaser.

METHODS OF LOGGING

Logging method, like fire protection, is a major factor controlling the productivity of cut-over lands, for it may and often does injure or destroy the advance reproduction and seed trees without which a

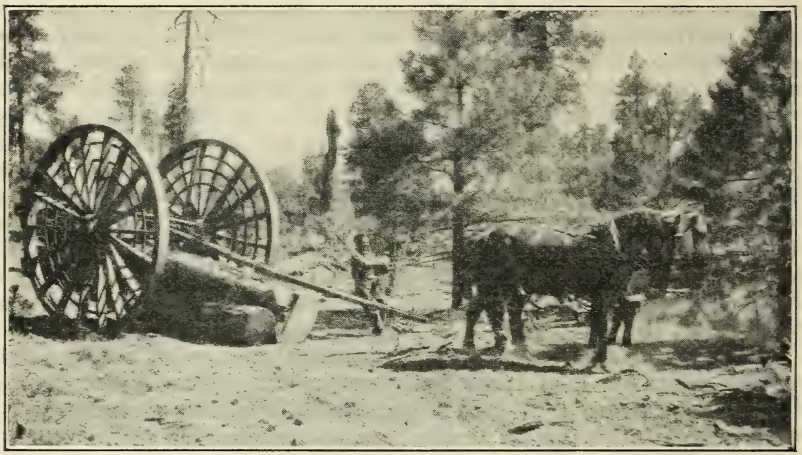

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FIG. 6.—BIG WHEELS NEVER ALONE LAY WASTE TO FOREST LAND

Young growth and seed trees are avoided in logging by the big wheels. Consequently less of the young forest is destroyed than by any other established method of yarding.

new forest crop is impossible. Careful consideration is therefore required of the effect of different yarding methods on the forest, and of their comparative efficiency and cost.

In California two general types of logging are in common use—animal and power. The former is represented chiefly by big-wheel yarding; the latter by both low and high speed donkeys, using both the low and high lead cable systems.

BIG-WHEEL YARDING

Big-wheel yarding equipment consists of a pair of 10 to 12 foot wheels, ordinarily horse drawn, with either a stiff or slip tongue. Logs are slung under the axle by chains (fig. 6). In the slip-tongue method the logs automatically drop and act as a brake when the wheels begin to run, and this system is used successfully on slopes up to 25 per cent. The stiff-tongue method lacks this feature and

is used only on level land or on very gentle slopes. The wheels are operated on roads swamped out from the landing, with short spurs to the individual trees or loads of logs which are bunched with teams. If brush or advance reproduction is lacking, scanty, or low in height, little swamping is necessary.

F-169220

FIG. 7.—THE EFFECTS OF BIG-WHEEL LOGGING SEEN FROM THE AIR

The big-wheel roads, as viewed by airplane, join the spur in irregular lines that rarely sweep the ground as destructively as in machine logging. This view may be compared with airplane views of machine logging in Figures 9, 11, and 14.

At present big-wheel yarding is used only in the east side yellow pine type and, to some extent, in the yellow pine–white fir of the same region. This discussion refers in the main to the first-named type in which big-wheel logging is characteristic.

The damage to seed trees is negligible, but there is considerable loss of seedlings, saplings, and small poles owing to swamping out roads. On a well-managed national forest cutting area reproduction

strips were laid out before logging and recounted after logging. Of an original 3,060 seedlings to the acre, 2,440, or 80 per cent, remained after yarding was completed. The surviving trees, too, were well distributed, for on 95 per cent of 40 small plots part of the original stand remained.

Similar strips on private land in the same operation show that 63 per cent of the advance reproduction survived, and that on 80 per cent of the one-hundredth acre plots (66 by 6.6 feet) some of the original stand remained.

The big-wheel method of yarding scars the forested area but lightly. Characteristically, reproduction on wheeled ground is bunched and the brush is thrown out in windrows paralleling the wheel roads, on which practically all advance reproduction is destroyed (fig. 7). On some areas a high percentage of the ground may be covered by the roads, and at times in the heavier stands of over 25,000 board feet to the acre fully 60 per cent of the reproduction is destroyed. The essential difference between national forest and private big-wheel yarding is that on the former fewer main roads are constructed and consequently a lower percentage of the entire area is covered.

Wheel yarding has several outstanding virtues. Even under the worst conditions it alone is never responsible for complete destruction of advance reproduction; and it does not seriously injure seed trees that may remain. If used intelligently and with reasonable care, it is the least destructive of any method of yarding now in general use. A wide experience with big wheels on national forest cuttings and an examination of many private areas provide adequate evidence that needless damage is seldom caused. Existing damage comes mainly from swamping out roads, and since this costs real money, unnecessary road construction is avoided, except in so far as inefficient supervision and labor result in a poor layout of roads. The area laid bare by landings is usually smaller in wheel logging than where donkeys or trucks are used.

Big-wheel yarding is not a cause of fires, and this ranks as one of its principal advantages. Donkey engines, on the other hand, are a constant risk, and on donkey operations perpetual care is required to avoid damaging and costly fires.

A serious defect of wheel yarding is that the windrows of slash left after yarding are always in the strips between roads, just where the surviving reproduction is. The burning of this slash, as it lies, either by controlled or accidental fires, is impossible without serious loss to seedlings and smaller trees that have survived logging.

DONKEY YARDING

GENERAL CHARACTERISTICS

There is a wide variety of forms of donkey yarding with power, but the general layout is similar in all of them. The essential part of the equipment is the power plant, which drives the drums on which a steel cable runs. One cable or "main line" is used to drag the logs in from the woods to the landing; another lighter cable or "back line" returns the main line to the woods. Logs may come in a direct line to the donkey or may be shunted around obstacles by

means of blocks or shear trees, the main line sometimes having several such angles in it.

The machines until recent years have been entirely of the low-speed type with the main line capable of an average speed, with half-loaded drum, of 250 to 450 feet per minute. With the introduction of two-speed engines, the rate has been increased till at present a line speed up to 1,000 feet per minute is claimed.

With the adoption of high speed, damage to both advance reproduction and seed trees increases. The incoming logs drag the ground bare along the trails and wipe out everything except the largest obstacles in their path. The extent of this damage, of course, depends on the percentage of the ground that is dragged,

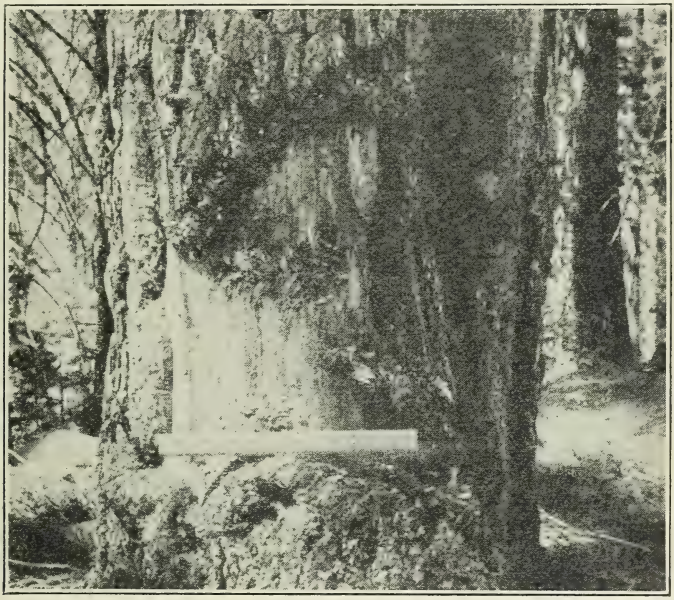

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FIG. 8.—SCARRED BY INCOMING LOGS

Donkey yarding can take little account of obstacles. This tree recovered from having a third of its bark torn off at the base, but many smaller trees similarly injured do not recover.

which in turn depends on the stand per acre, the frequency with which the main line is changed, and whether timber is yarded in short lengths or entire trees.

The heavy cables are also a source of damage, for as power is applied they slash through a horizontal segment, knocking off limbs, breaking small trees, raking off bark, and even smashing the tops out of seed trees.

The more important variations of this general type of logging will be discussed in detail as to their effect on forest production, and their comparative efficiency as logging methods.

GROUND-LEAD YARDING

The effect on reproduction of the ground-lead method with low-speed machines, where the lead block is placed within a few feet of

the ground, has been studied on a typical national forest cutting area. Strips of one one-hundredths acre, 66 by 6.6 feet, were laid out and tallied before and after logging. Before logging 1,515 seedlings per acre were found; after logging 975, or 64.4 per cent, remained. These were well distributed, only 7 per cent of the small plots showing complete destruction of advance reproduction. While this single series of data can not be regarded as conclusive, it indicates that about two-thirds of the advance reproduction, well distributed, survives.

Similar data were also obtained for an operation on private land. In this case, of 1,280 seedlings to the acre in the virgin forest 605, or 47.3 per cent, remained after yarding. Although over half of the advance reproduction was destroyed, on only 1 out of 16 plots did logging wipe it out entirely; 94 per cent of the plots were left with advance reproduction.

These data again, although not conclusive, agree well with experience in showing decidedly more damage on unregulated private cuttings than on supervised national forest cuttings. The latter may be considered to show what can easily be done if donkey yarding is properly regulated; the former, what results from unregulated yarding. Although the survival of 47 per cent of the reproduction seems rather low compared with the 80 per cent on national forest wheel-logged land, it must be recognized that with any type of machine logging considerable loss is to be anticipated. The saving of practically half of the reproduction well distributed is very far from denudation.

Examination of many operations, both national forest and private, old and new, shows that complete destruction of advance reproduction or of seed trees is never chargeable to this method alone. On the permanent sample plots, for example, after ground-lead yarding, 1,270 and 5,460 seedlings per acre survived on typical areas in the yellow pine and mixed conifer types, respectively.

This type of yarding is likely to be adjudged as more destructive than it really is, particularly if seen at the time of or soon after logging. The incoming logs and the line scar the bases of many trees, the fresh scars being very noticeable. (Fig. 8.) Data taken on the permanent sample plots show an average of 6.9 per cent of the remaining trees injured in this fashion, but also show that recovery is rapid and death rate low. This figure is, of course, a minimum, and on unregulated private land the percentage of trees injured sometimes runs as high at 25. Wounds which expose the heartwood are known to result commonly in infection by wood-destroying fungi. Logging wounds usually do not go so deep, but even more superficial wounds, if large enough, may prove to be a source of danger to the stand left after logging.

Ground-lead logging makes a characteristic pattern. (Fig. 9.) Near the machine a high percentage of the ground is dragged, because of the convergence of the many trails; but toward the outer edge of the logged area damage becomes progressively less.

The emphasis on saving of advance reproduction, it may again be noted, would be of merely academic interest, were it not for the fact, discussed in detail elsewhere, that the principal part of the second stand, particularly in east side yellow pine, must come from that source.

So far as the data presented go, and examination of many cutting areas both national forest and private confirms this view, low-speed, ground-lead yarding is a satisfactory method, although distinctly more damaging than animal yarding. The wheels average 71.5 per cent survival, the donkey engine 55.5 per cent. For that reason, if for no other, and despite the good points of donkey yarding, animal (wheel) logging on ground to which it is adapted should be encouraged by all possible means.

F-169327

FIG. 9.—GROUND-LEAD YARDING VIEWED BY AIRPLANE

Radiating skid trails destroy a considerable part of the young growth, but in the intervening sectors no material damage is caused, and the net result is reasonably productive land, if fire is kept out.

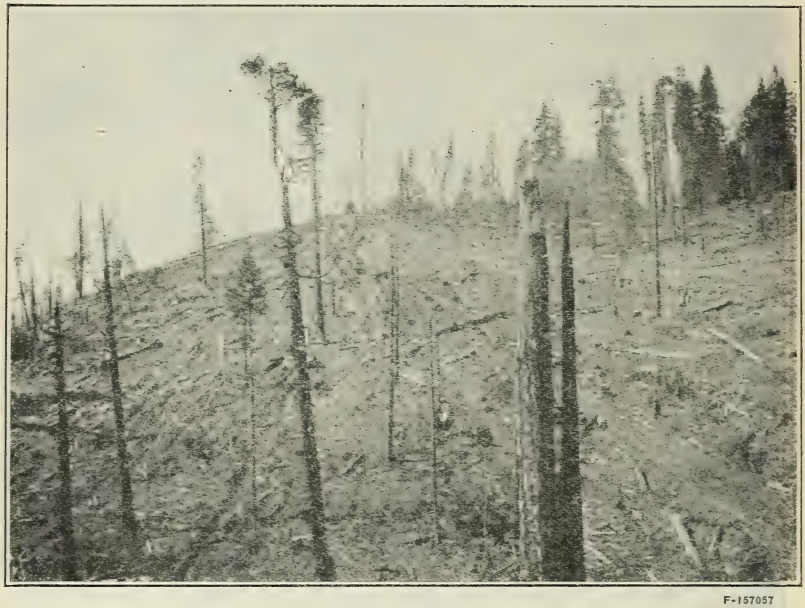
HIGH-LEAD YARDING

Imported from the fir forests of the Pacific Northwest about 1917, the high-lead system of yarding spread rapidly in the California pine region, and in 1921, out of 25 important operations, 19 were using the high lead either wholly or in part.

The equipment used is essentially the same as for ground-lead yarding, except that the main lead block is placed on a spar tree

up to 125 feet above the ground. This, of course, gives a lifting effect on incoming logs, the degree varying inversely with distance from the spar tree. Loggers generally estimate that the lift disappears at a distance from the spar tree of five times its height.

The high-lead system, especially when high-speed engines are used, results in very serious damage, particularly in the zone surrounding the setting, and this is apparently inherent in the method. (Fig. 10.) The tightening up on the line in changing snaps out the tops of many saplings, poles, and potential seed trees, while the lift on incoming logs means that they hit obstacles, among which are trees, higher above the ground than with the ground lead, and many of the possible seed trees are broken off or pulled down in this manner. The



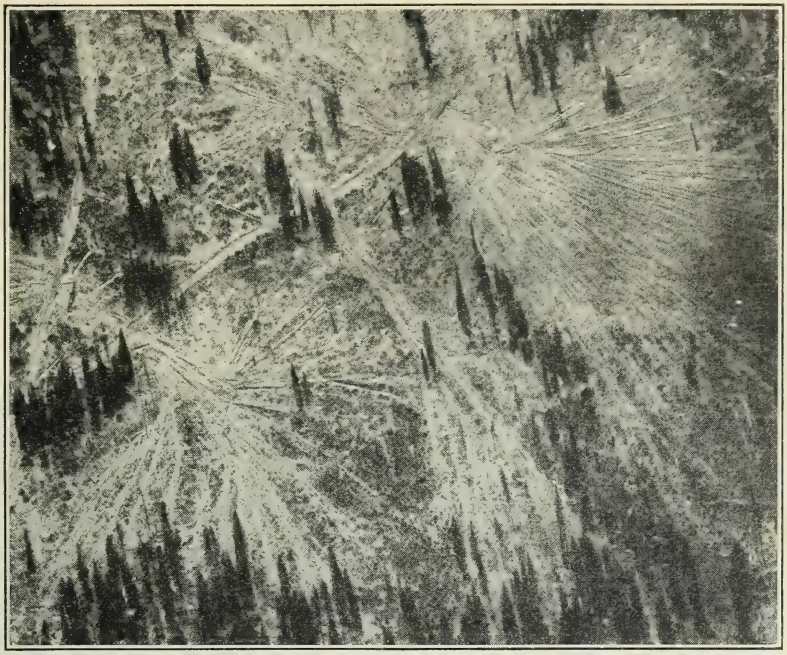
F-157057

FIG. 10.—A BARREN SWATHE LEADS UP TO THE SPAR TREE

The terrific power of high-lead yarding wipes out young growth and smashes seed trees where the trails converge. Where future productivity of the land is hoped for, this form of yarding is highly unprofitable.

high lines result in stripping the crowns, a more serious form of injury than trunk wounds, from the standpoint of immediate growth. In typical ground-lead yarding the line is changed as infrequently as possible, and it follows that a relatively small percentage of the total ground area is dragged by incoming logs. With the high lead, on the contrary, fewer logs come in over a single trail and logs do not hold to established trails, so that a much higher percentage is dragged, and the damage to reproduction and even to trees up to 10 and 12 inches in diameter at breast height varies on the average directly as the area covered by log trails.

Comprehensive data obtained by E. N. Munns on several typical high-lead settings are summarized in Table 2.



F-169309

FIG. 11.—HAVOC WROUGHT BY HIGH-LEAD AS SEEN FROM THE AIR

A large proportion of the ground has been dragged bare by the converging lines leading up to the spar tree. Within 500 feet from the spar tree the damage to young growth amounts practically to denudation.

TABLE 2.—*Effect of high-lead yarding on advance reproduction up to 4 inches diameter breast high*

Distance from spar tree	Trees per acre before logging	Trees per acre after logging	
Feet	*Number*	*Number*	*Per cent*
200	1,347	3	0.2
400	1,689	44	2.6
600	1,585	297	18.7
800	1,628	607	37.3
800+	2,694	1,479	54.9

At the outer edge of the logged area the damage is of about the same magnitude as that already found for ground-lead logging. Between 500 and 800 feet it is considerably higher than for the ground lead. At about 500 feet out from the spar tree the damage is practically complete, as the data clearly show. There nothing survives, and the regularity with which this condition is found on all high-lead settings makes it evident that it is inherent in the system. (Fig. 11.)

The ground-lead system, especially with low-speed engines, does not commonly result in breaking off or pulling down seed trees

(fig. 12), but this is a strongly marked characteristic of the high lead, and many trees 16 to 20 inches in diameter are destroyed. A sample strip 30 chains long run through a typical high-lead area and including both the inner and middle zones showed that 77 per cent of all trees over 12 inches in diameter had been pulled down, or had had the tops snapped out.

Even in the east side yellow pine type this method has been used to some extent, although there appears to be no topographic reason for so doing. One example, a typical one, may be cited. Up to recent years one company logged with animals, and though the timber had been practically clear cut the damage to reproduction was so slight that the area now, about 10 years after logging, presents a fine appearance. Barring fire, the future productivity is

F-157132

FIG. 12.—HOW GROUND-LEAD YARDING SAVES YOUNG GROWTH

Timber can be machine logged without destroying the advance reproduction, upon which the future forest relies. Ground-lead yarding, as in this case, usually leaves ample young growth.

assured. A striking contrast is an area in similar country, about 6 miles away, logged in 1917–18 with high lead. (Fig. 13.) An examination shows not over 25 per cent of the area left with advance reproduction surviving and the distribution very poor indeed. The contrast in condition of reproduction between these two areas is chargeable entirely to the use of the high-lead method.

The Forest Service, after allowing the high lead on selected sale areas as an experiment, has definitely decided that its use can not be sanctioned, and has placed the maximum permissible height of the lead block at 35 feet. This has been called the modified-lead method. National forest experience is that even with every effort to prevent excessive damage destruction is inherent in the high-lead method. Only occasional high-lead settings are found where complete wiping out of seed trees and young growth is avoided

near the machines, because low power, low-speed machines, and the elimination of tight-lining have been combined with a partial cutting of the area.

The only possible conclusion to be derived from a study of the high-lead method on the ground is that with rare exceptions its use is incompatible with continued forest production. At least as far as the inner zone in high-lead logging is concerned, the question is not whether the new stand will be fully or only partly stocked, but whether there will be a new stand at all or even a possibility of a new stand. Destructive logging acts in the same manner regardless of timber type.

F-157126

FIG. 13.—HOW HIGH-LEAD YARDING DESTROYS YOUNG GROWTH

By pulling out and breaking off the small trees, high lead commonly leaves cut-over areas with only scattered remnants of a stand.

Modern high-power and high-speed logging is responsible for starting many deep gullies, which readily become enlarged through erosion. One serious effect of destructive lumbering is thus likely to be heavy erosion and reduction in summer flow of streams, a matter of outstanding importance to the agriculture of the Sacramento and San Joaquin Valleys.

MODIFIED-LEAD YARDING

The modified-lead method, with lead blocks up to 35 feet above ground, has not been studied in detail. Examination of areas logged by it shows that it is somewhat more destructive than ground leading, but that it does not result in the tremendous damage of the high lead. With low-speed machines it is a satisfactory method.

HIGH-SPEED YARDING

As logging machinery has developed, the cry has been ever for greater and greater line speed and at present a rate of 1,000 feet per minute is claimed for some machines, compared with 250 to 450 feet per minute for the older types. High-speed machinery may be used with the ground, low, or high-lead system, and is destructive with any one of them. Such yarding even without high lead may and often does approach in destructiveness the high-lead system. Incoming logs hit obstacles, such as clumps of reproduction, with a smash that greatly increases the damage. The lighter and shorter logs especially do not hold the trail as they do with low-speed yarding, but whip around, tearing up reproduction on both sides of the trails and smashing into and breaking the larger trees.

The Forest Service has tried this system experimentally on national forest cuttings, and has been compelled to limit the speed of line to 500 feet per minute. Beyond this point destruction increases very rapidly, and a maximum of 600 feet per minute is all that is possible if lands are to remain in a productive condition.

SKIDDER YARDING

The steam skidders used in California pine are a specialized type, adapted to use only along railways. They are more readily moved than donkeys and in practice occupy a setting for a much shorter period than the latter. Skidders make a very characteristic pattern of straight, slightly radiating lines, a few from each setting (fig. 14), with no pronounced development of the inner zone of complete destruction as in the case of much donkey logging.

Most skidders operate with the lead block in an **A**-boom at an elevation similar to that under the modified lead, and when used with low-speed lines this is a satisfactory method. One large, two-line machine with high-speed line has proved very destructive, because of the characteristic whipping of the line and the smashing effect of incoming logs. Except for this the machine is acceptable, for its trails are clear-cut and narrow, cover only a small percentage of the ground, and leave the surviving reproduction well distributed. In practice, machines of this type have been used on level or gently sloping ground, where railway spurs can be built cheaply and close together. On such land, which is perfectly adapted to animal yarding, the use of any type of machinery is unfortunate, since damage is nearly always greater than if animals were used.

A modification of skidder logging, as used in the Southwest, where logs are skidded into runways by teams and yarded in a straight line to the landing, seems to be the least destructive method of power logging. This system might be used in the California region, unless size of logs proves to be too great.

TRACTOR LOGGING

Caterpillar tractor logging, though a recent innovation in California pine, already displays great possibilities and is likely to replace in part big-wheel, donkey, and skidder yarding. The most effective layout seems to be 10-ton tractors of the tracklaying type,

used as motive power for a special type of big wheel. Bunching is done by 5-ton tractors. On grades up to 30 per cent, even with considerable loose rock, this system has proved its superiority to both big-wheel and donkey yarding. On slopes from 30 to 45 per cent logs are commonly skidded on the ground by tractors.

The operating advantages of tractor logging are low yarding cost compared to other methods, reduced amount of railroad construc-

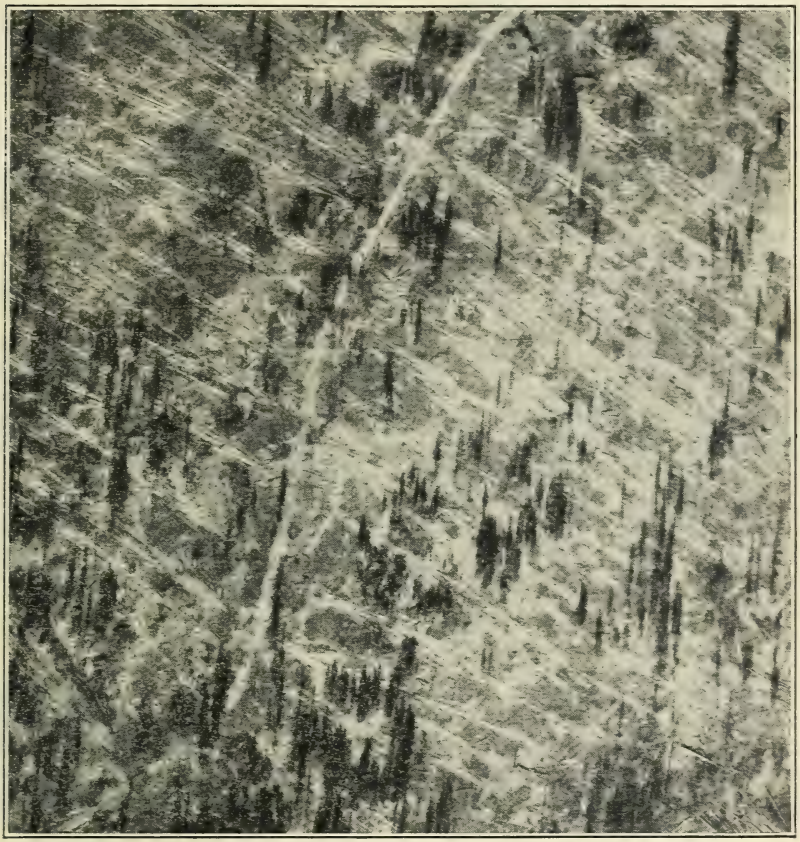


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FIG. 14.—SKIDDER YARDING RESULTS IN A CHARACTERISTIC PATTERN

The California type of steam skidder, used only along railways, benefits the cut-over land by its mobility, as shown in this bird's-eye view.

tion, flexibility of operation, particularly in logging open and scattered forests, very low fire danger, and small amount of swamping required for roads.

Damage to young growth and seed trees appears to be little greater than with the big-wheel method. On one operation 20 per cent of the total area was covered by yarding roads on which nearly all young growth was destroyed. Between the roads, damage was slight, and for the area as a whole, not over 30 per cent of the reproduction was wiped out.

Large poles and seed trees are rarely injured and never destroyed by tractors, for the machines lack the power to overcome such obstacles. As in big-wheel yarding, the roads avoid as many obstructions as possible.

Tractor logging as at present used thus ranks as one of the most satisfactory methods, both from the standpoint of logging efficiency and from that of forest productivity. On ground of moderate steepness, such as is characteristic of practically the entire east slope of the Sierras, tractors are preferable to donkeys because of greatly reduced fire danger, and materially lower damage to advance growth and seed trees.

OTHER METHODS OF YARDING

Yarding with "bummers" or spool carts, with animal power, is perhaps the characteristic system in the Blue Mountains, but it is practically unknown in the California pine region. It is used on moderate slopes with success, and is said to be more efficient than donkey yarding in the timber of that region, which differs very slightly from that in the California pine region. This method, too, is very satisfactory, causing minimum damage to advance reproduction and practically none to seed trees.

It is remarkable that in two near-by regions, with essentially similar timber and topography, such as are found in the Blue Mountains and in the east side of the Sierras, such radically different logging methods should have been accepted by operators. In general, it appears that while the northern operators have tested and rejected donkey in favor of animal yarding, the California operators, having tried out only the big-wheel system of animal yarding, have tended toward a general adoption of donkey logging even on easy ground, a most unfortunate thing from the standpoint of forest productivity. Tractor logging is likely to reverse this tendency to some degree.

COMPARATIVE COSTS OF DIFFERENT LOGGING METHODS

Two general questions have been presented in the preceding discussion that require study: (1) What are the relative costs of animal and steam logging on ground suitable for animal logging? (2) What additional cost must be recognized if a method, which has been shown to be absolutely inimical to forest production, such as the high lead, is discontinued?

ANIMAL VERSUS STEAM LOGGING

The use of steam logging on ground suitable for animal logging has been found unfortunate from the standpoint of the forest, because of the greater destruction of young growth and seed trees. Even low-speed ground yarding, although not in the same class as high-lead yarding as a destructive agency, is still in general more damaging than wheels. What then is the relative cost of the two principal methods where used under comparable conditions?

On one large operation with excellent cost records, it was found that over a period of five years the cost per thousand board feet on easy ground was from 33 to 59 cents per thousand less for wheels than for donkey logging, reckoning direct cost exclusive of over-

head. Expressed in percentages, power yarding was from 8 to 15 per cent more expensive than animal yarding.

The experience also of Oregon operators leads to the conclusion that on animal ground some method of animal yarding is cheaper than is steam logging. Further critical study is needed in California, but it is at least an open question whether some form of animal logging will not prove to be most efficient and at the same time least damaging, particularly in most of the east side yellow pine type.

Under average conditions it is generally recognized that wheels are the cheaper of the two methods, but under some circumstances there is a disinclination to use them, because of the carrying charges for horses over winter, the skilled labor required, and the difficulty of procuring common labor for swamping. Wheels, too, are not as adaptable as donkeys, for the latter can be used on any type of ground whereas the former are impossible with slopes of over 20 to 25 per cent.

HIGH-LEAD AND HIGH-SPEED VERSUS LOW-SPEED, GROUND-LEAD YARDING

At the time of its introduction great claims were made for the superiority of high lead over ground lead as a method of logging. It was anticipated that considerable savings in logging cost would be effected by using the new method. But that for the relatively light stands in the California pine region the high-lead system has not been altogether a success is evident from the action of some of the larger operators, at least five of whom, after a thorough try out, have abandoned the system and returned to the ground lead, simply because high lead was not found to be an effective and economical logging method, regardless of its effect on the forest.

A comparative study of the two methods by Price (*12*) showed as its salient feature that in all the steps of yarding, hooking time, "in" time, delays, etc., for most yarding distances up to 1,200 feet, the average maximum yarding distance, ground lead had a consistent superiority over high lead. Expressed as output per man-hour, the comparative results of the two methods are given in Table 3.

TABLE 3.—*Output per man-hour with high and ground lead*[1]

Yarding distance	With high lead	With ground lead	Yarding distance	With high lead	With ground lead	Yarding distance	With high lead	With ground lead
Feet	*Bd. ft.*	*Bd. ft.*	*Feet*	*Bd. ft.*	*Bd. ft.*	*Feet*	*Bd. ft.*	*Bd. ft.*
100	720	980	600	440	580	1,100	300	340
200	930	900	700	390	520	1,200	300	300
300	950	810	800	350	470			
400	780	730	900	320	420	Average	529	590
500	560	650	1,000	310	380			

[1] Ordinary delays included.

On the average, using the results of this study, the output is 11 per cent greater for ground lead than for high lead. In this result there is not included the cost of rigging the spar tree, nor on the other side is there included the supposed longer life of cable on high lead.

In an investigation of the different donkey-logging methods which served to bring out what advantages there are in high-lead yarding, Berry (*3*) concluded that high lead means a small saving in cable cost, and that smaller engines can be used with high than with ground lead. There is a small advantage over ground lead on moderate uphill pulls, and probably a greater advantage on steep and rough ground, but little or no advantage, possibly a disadvantage, on downhill and sidehill logging. High lead simplifies the logging layout, and is popular with workmen because less effort is required. It has little or no operating advantage at the spar pole over the modified-lead method.

It seems fair and conservative to say that the high-lead system as a logging method has shown no decided advantage over the ground lead. On the other hand, it is tremendously more destructive to the forest, and on a considerable part of each setting leaves the ground denuded.

Even if high lead should prove to be slightly cheaper than ground lead, as broadcast burning is cheaper than partial slash disposal, the method is so definitely in the class of major destructive agencies as to be incompatible with forest production, and its use, except under very special conditions, should be discontinued.

The new forest depends absolutely on the saving of young growth and seed trees; and any method of logging which leaves less than half of the young growth intact defeats the purpose of keeping the land productive. With any method except high lead or high speed, damage to young growth and seed trees can be so controlled, at slight extra logging cost, as to leave a reasonable start for a new forest. Fortunately the very destructive methods of yarding appear to have little, if any, operating advantage over the less damaging methods, except perhaps on very rough or steep ground, as in parts of the mixed conifer type.

A further point to remember is that any kind of machine yarding, with the exception of caterpillars, is more destructive to advance reproduction and seed trees than animal yarding, and when used on ground suitable for the latter is rarely justifiable.

INTENSITY OF CUTTING

QUESTIONS INVOLVED

In addition to fire and method of logging a third major factor which regulates the amount of new growth on cut-over forest lands is intensity of cutting. This is because systematic reservation of seed trees is necessary to provide restocking where advance reproduction is absent or scanty in the virgin forest or where it is destroyed in the process of logging, as well as to insure cut-over lands against denudation from subsequent fires.

On most cuttings, the advance growth left after logging is more or less scattered, utilizing only part of the productive power of the land. To complete stocking, seed trees are necessary. An additional reason for leaving seed trees is the occasional fire on cut-over lands, which may occur even with systematic protection and which commonly destroys the young growth. If seed trees have been left, young growth will gradually come back after fire; if there are no

seed trees, the land will remain unproductive for many decades. In all cases, though reproduction from seed trees is generally slow, it must be relied on to complete the restocking of cut-over lands. Under present conditions no alternative is possible.

It is obvious at the start that in planning to leave trees for seed the selection of small trees is desirable, for the higher values in the large trees would render their reservation costly to the operator. It is further evident that some mechanical form of selection of these trees will be the most suitable, for the selection must be made in the process of cutting and by woods labor and camp foremen. Establishing a diameter limit for cutting is, for the purpose of simple timber-growing measures, a logical and usable system, primarily because it is already in use on most operations and can readily be applied everywhere.

The problem, then, is to determine the number of seed trees per acre that will be necessary to insure stocking of cutting areas with the least alteration of existing practices and the least additional cost, and also the diameter limit for all species that will most nearly provide the number of trees desired.

The solution of the problem involves an answer to several questions:

(1) What is a seed tree?
(2) What number of seed trees is required for restocking?
(3) Are small seed trees available in different forest types?
(4) How many seed trees are left in current cutting practice on private lands?
(5) What is the simplest method of preserving seed trees?
(6) How large an investment is required to provide seed trees?

WHAT IS A SEED TREE?

The first essential is to leave trees of a size that can be counted on to produce seed immediately after cutting, for then seedlings establish themselves more readily than after brush has invaded the ground. Within what diameter limits this may best be accomplished is indicated by general observations on many sample plots and cut-over areas, and more particularly by detailed study of cone production on two permanent sample plots in the east slope yellow pine type. It was found that the percentages of trees in each diameter class bearing no cones, which at 10 inches is 100, drops rapidly, reaching 8 per cent at 18 inches and zero at 20 inches. The percentage of trees producing a light crop rises rapidly, reaching the peak with the 16-inch class, and then drops more gradually, reaching the zero point at 32 inches. Trees producing a medium crop first appear at 18 inches, increase to a peak with the 28-inch class, and then drop. Trees producing a heavy crop do not show up till a diameter of 28 inches is reached, after which the curve appears to be essentially the same as for the other categories. The study indicates that yellow pine trees 18 and 20 inches in diameter have considerable cone production, whereas smaller trees bear at best only a light and uncertain crop. In the Southwest, Pearson has found that yellow pines smaller than 20 inches in diameter are ineffective seed producers (*10*).

On certain of the yellow pines studied, the cones per tree were counted. Though the data are not wholly conclusive, they confirm

experience that the larger the tree the more cones it produces. A 30-inch tree on the average produces four times as many cones as a 20-inch tree. But this is not the only phase of the matter to be considered. Using the curved figures for cones per tree and average volumes in board feet for trees of different sizes, the average investment in board feet per cone produced has been computed for each diameter. This indicates, remembering that finality is not claimed for the conclusions, that beyond a diameter of 18 inches the number of board feet per cone increases rapidly. It takes 3.8 board feet to produce a cone on 18 and 20-inch trees, and nearly twice as much, or 6.5 board feet, on 30-inch trees; thus on the average an investment of 1,000 board feet in small trees should produce at least 50 per cent more cones than an equal investment in large trees of 30 inches in diameter. It seems clear that if trees are left solely for seed production those of a size having the largest cone production per unit of merchantable volume should be selected, which according to the data in hand are trees 18 to 20 inches in diameter.

Similar detailed studies have been impossible for the other important species, but it is reasonably certain that the relation of size to seed production is essentially the same for all species.

But having determined the most desirable size for seed trees, the owner needs to know how many of these trees to leave in order to complete the reforesting of his land, and whether a diameter-limit cutting to the optimum cone-producing size will in fact secure for him the requisite number.

NUMBER OF SEED TREES REQUIRED

An extensive and typical national forest cutting in the yellow pine type, marked primarily with the idea of leaving only seed trees, rather than trees for growth, and now showing very good distribution of seed, will help in deciding the number of seed trees necessary to give reasonable assurance of restocking. The data used are based on a careful 10 per cent cruise, or two strips per 40 acres, made by A. E. Wieslander on over 2,000 acres of cut-over land. The average number of uncut trees 18 inches in diameter and over (that is, seed trees), using the "forty" as a unit, is 3.9 per acre, whereas the number most frequently found is 3 per acre, with 2, 4, and 5 trees also common. These seed trees range in diameter from 18 to 34 inches, with the great bulk between 18 and 26 inches in size. Their distribution is excellent, for that is a specific requirement in a national forest cutting. The average volume of seed trees, 400 board feet, corresponds to an average diameter at breast height of slightly over 22 inches.

These data are worthy of considerable emphasis because they indicate the method followed on national forest cuttings by experienced markers, and because the problem of interpreting the data is not complicated by trees left for growth rather than for seed, as is the case on cuttings in mixed types. Study of this area shows that the trees scattered seed everywhere, and it seems fair to conclude that, *given careful selection of seed trees* for position and crown characteristics, three trees per acre are sufficient to insure restocking.

The data also indicate that where it is desired to reserve the smallest practicable trees and the minimum number of them as seed trees, by mechanical rather than by individual selection, this may be accomplished by cutting down to a general diameter limit of 20 inches. (Fig. 15.) The trees caught within this limit will be capable of producing seed regularly and will at the same time afford the largest cone production per unit of volume. They will, however, be spaced irregularly, particularly in the pure yellow pine type where the pines tend to occur in groups. Also the quality of the trees as seed producers will unquestionably be lower than when such trees are individually selected. To compensate

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FIG. 15.—DIAMETER LIMIT CUTTING LEAVES LAND PRODUCTIVE

In the mixed conifer type, here shown, cutting to a minimum diameter of 20 inches leaves ample small, thrifty trees that will furnish seed and at the same time make rapid growth toward a second, intermediate cutting. In most of the types this holds true, pure yellow pine being the most conspicuous exception. Land in this condition is an asset to the owner.

for these disadvantages, a minimum of four small seed trees will be needed under the diameter-limit method of selection to attain the same degree of restocking of cut-over lands that three trees per acre individually selected will make possible.

The specific data cited do not form the only basis for selection of 20 inches as the diameter limit for cutting, or four trees per acre as the minimum number necessary; but they are given in detail as being representative, and examination of seed production and seed trees on many cut-over areas confirms the conclusions. Trees smaller than 20 inches are occasionally found bearing good crops of cones, and in some cases fewer than four trees per acre appears to be sufficient for restocking; but for a general working average those limits are justified.

THE NUMBER OF SEED TREES LEFT IN CURRENT CUTTING PRACTICE ON PRIVATE LANDS

The degree to which the minimum need of four 20-inch trees per acre is met on private cuttings is exceedingly variable. Timber type, the state of the market, and the opinion of individual companies, all affect the closeness of cutting.

To determine the number of seed trees left in private cutting, cruise strips aggregating over 96 miles in length were tallied in the principal types, embracing old and new cuttings and covering all important operations in the region.

THE YELLOW PINE TYPE, EAST SLOPE

In the yellow pine type of the east slope, 15 samples were taken on private land, the earliest going back to cuttings of 1895. Of these, 8 areas, or 53 per cent, averaged less than 1 tree per acre 18 inches or more in diameter; 1 area, or 7 per cent, had from 1 to 2 such trees; 2, or 13 per cent, had 2 to 3 seed trees; 1 had 3 to 4 trees; and only 3, or 20 per cent, had an adequate number of seed trees, that is to say, 4 or more per acre. The number of trees from 12 to 16 inches in diameter likewise was low, averaging but 3.3 per acre. Such trees will in time, say 15 to 25 years, build up their crowns and produce fair quantities of seed, but little immediate help can be expected from them.

In general, on recent cuttings in this type, less than 1 tree of 18 inches or over is left, in comparison with an average requirement of 4 trees per acre on national forest cuttings, where marking has been primarily for the purpose of obtaining reproduction. It is to be noted, too, that the average figures for private cuttings tend to present the condition in a more favorable light than would more detailed figures, owing to the fact that the sample strip arbitrarily laid out may run through a clump of trees on an otherwise very scantily provided area and the average for the entire area be raised thereby.

Patchy or scattering distribution of trees left after cutting is typical of yellow pine areas. If advance reproduction is absent or if it has been destroyed by logging, an impossible task is put upon the few remaining trees left by present cutting practice. Regeneration is most difficult in the yellow pine type at best, even with the abundant seed furnished by the untouched virgin forest. On cut-over areas the seed supply is seriously reduced and the destruction of seed by seed-eating rodents is likely to remove most of the small quantity that remains. Where the required trees are left, as on national forest cuttings, or where high diameter limit has been observed in cutting, the future productivity of the land is assured. (Fig. 16.) It appears, however, that cutting on private lands in the east side yellow pine type is generally so close that hardly any trees of seed-bearing size are left.

On many small areas advance reproduction is present and survives logging in sufficient quantities to insure future productivity, but this appears to happen nowhere over large areas. In general, advance reproduction is too uncertain and unsafe a method to depend on exclusively for regeneration. Because of relatively recent fires, ad-

vance reproduction on areas as large as a township is almost always patchy, and seed trees, of course, must be relied on where reproduction is not present. Even where it is present, the loss by logging and danger from fires make it essential to leave seed trees.

THE YELLOW PINE–SUGAR PINE, MIXED CONIFER, AND YELLOW PINE–FIR TYPES

In an intensive study of this group of types, 19 out of the 27 sample strips, or 70 per cent, gave 4 or more seed trees per acre 18 inches or over, and in most cases there was a good representation of trees 12 to 16 inches in diameter. In recent years, however, the tendency to clear cutting has been evident on practically every operation. It was illustrated on 4 of the sample strips, or 15 per cent, where the diameter limit in cutting was well below 18 inches, and less than 1 tree per acre of any species was left.

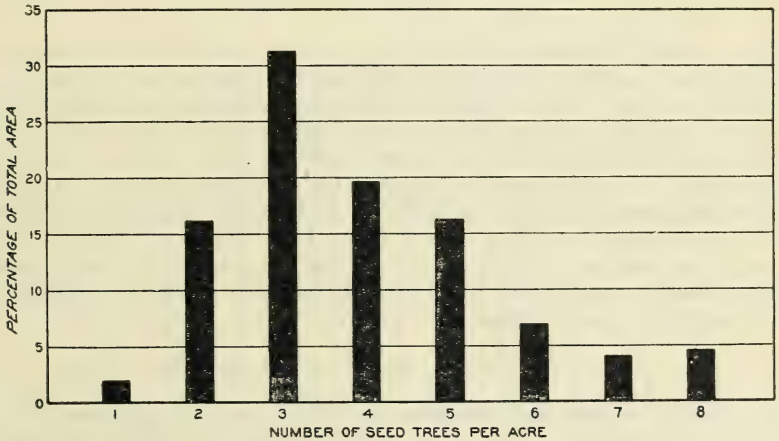

FIG. 16.—Distribution of trees left for seed on an area where adequate reseeding resulted. The trees left for seed on this area ranged from 18 to 34 inches in diameter, but the average volume was 400 board feet, indicating an average diameter of 22 inches only. While 3 trees per acre was the number most commonly found (that is, on 31 per cent of the area), the average for this whole area of 2,000 acres in the yellow pine type was 3.9 trees to the acre. This is a typical national forest cutting where excellent distribution of seed trees has been insisted on and where new reproduction indicates a correspondingly excellent distribution of seed

In general, the results of present practice are not so discouraging as in the east side yellow pine type, although a deficiency in the number of pine seed trees is evident. In only 2 out of the 27 strips were 4 pine seed trees per acre left, and in only 10 were 2 or more left. This selective cutting, of course, will result in a decrease in the percentage of pine in the future stand, especially when it is remembered that the bulk of advance reproduction is of the firs and cedar, and not yellow or sugar pine.

Selective cutting on private land in these mixtures of pines, firs, and cedars takes a wide variety of forms. The most unfortunate, perhaps, is one in which only unmerchantable incense cedars are left. From that point to where only pine is cut, leaving a heavy stand of fir, insufficiently opened for the development of yellow pine seedlings, many variations are encountered, depending on the individual company's interpretation of the market for firs and cedar.

Generally speaking, a large number of thrifty trees are available for leaving in these types; but, as the tendency is to cut to a low diameter in all species, the contrast between national forest and private cuttings is even more marked here than in the yellow pine type.

SUGAR PINE–FIR TYPES

In most cases in the sugar pine–fir type, plenty of seed trees (18 inches or over) are left, but of fir rather than sugar pine, for the cutting is apt to be selective and to eliminate the more valuable species, resulting in the conversion of the type to fir. This is particularly unfortunate because it is here that the sugar pine reaches its best development. Only the presence of advance reproduction of sugar pine will prevent this outcome. In such cases the new stand will not differ greatly from the old.

YELLOW PINE TYPE, WEST SIDE

In private cruising practice, the yellow pine type of the west side includes large areas of what is here treated as the mixed conifer type. Pure yellow pine, though economically very important wherever found, does not cover a high percentage of the total forest area of the west slope. Only a few cuttings were found. In these the practice, as on the east side, tends toward clear cutting. On one interesting area, cut over in 1911 to a diameter limit much below seed production size, the small trees left are building up their crowns but are not yet a factor in seed production. Such areas will in time be restocked, but the low diameter limit of the cutting will result in a long regeneration period.

WHITE FIR–RED FIR AND RED FIR TYPES

As there is so far little cutting in these types, strips were run on only two operations. On one of these the practice is to cut practically clear, whereas on the other only the better trees are removed. Little is known regarding the silviculture of the fir types. Windfall and wind-breakage are likely to prove a larger factor than in the types in which the pines are important; but, on the other hand, reproduction after cutting will probably be much easier to obtain.

GENERAL TENDENCIES ON PRIVATE CUTTINGS

Private cutting practice in the pine regions thus discloses several important tendencies, which should be altered if an adequate seed supply is to be insured.

The cutting of yellow and sugar pines on private operations generally and in whatever type they may occur is already being carried to a diameter limit below the seed-bearing size. This has been a progressive tendency ever since logging began in the region, and in pure pine stands now tends to leave the areas without seed trees and at best but partly stocked where reproduction is present and survives logging.

Douglas fir, white fir, and incense cedar are not generally cut to as low a limit as the pines, and in the mixed types usually sufficient seed trees of these species are left to restock the area. That a few

operations, however, are already cutting all species to a diameter of 12 to 16 inches indicates an unfortunate trend.

In mixed stands, current practice tends to eliminate the pines as a factor in the next forest, so that except for the chance occurrence and survival of advance reproduction the new stands will consist largely of the less valuable firs and cedar.

THE NUMBER OF SEED TREES OBTAINABLE WITH DIAMETER-LIMIT CUTTING

The representation and distribution of diameter classes are of first importance in determining the efficiency of the diameter-limit method of obtaining sufficient seed trees. Obviously, if the 20-inch diameter limit is to be adopted, there must be enough trees already on the ground to leave for the purpose intended. In studying this question, no method is superior to that of using stand tables, based on timber survey tally sheets.

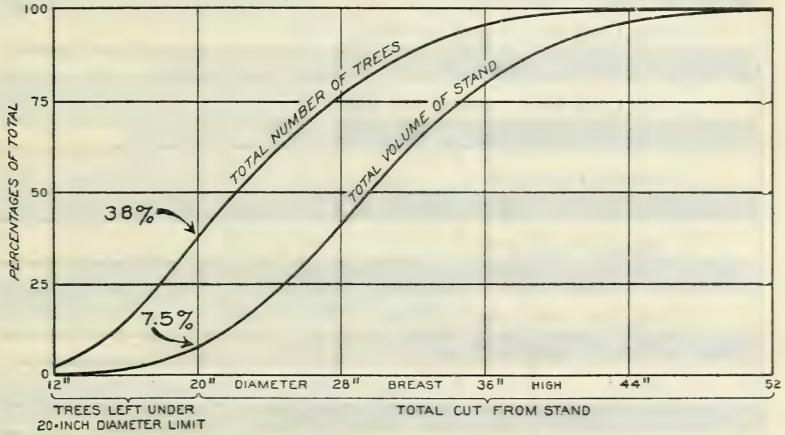

FIG. 17.—Percentage distribution of trees and volume of stand, by diameters. While 38 per cent of the total number of trees on this area are left standing by an application of a 20-inch cutting limit, the curve for total volume of stand shows that this considerable number of trees amounts to only 7.5 per cent in volume. The whole relation of number of trees to volume in a typical stand is well shown in this analysis of their distribution by diameters

EAST SIDE YELLOW PINE

In two stands of 410 and 640 actual measured acres in east side yellow pine, the representation of diameter classes and the corresponding volumes of each were determined. In the pure yellow pine area there is a dearth of trees 10 to 16 inches in diameter, and 18 and 20 inch trees average four per acre; whereas in the yellow pine with a slight admixture of white fir there are decidedly more small trees. In either of these stands the average number of seed trees per acre would be ample for restocking with cutting to a 20-inch limit. Figure 17 indicates that of the total number of trees, 38 per cent are 20 inches in diameter or smaller, but that these trees make up only about 7.5 per cent of the total volume of the stand, or in this case about 1,000 board feet per acre. For the extensive stands of which this is a fair sample, such an investment in seed trees does not appear excessive.

In two other and more representative townships in the east side yellow pine type the average number of potential seed trees (18 and 20 inches combined) is 1.6 per acre, representing about 500 board feet per acre, or 3 per cent of the total stand. Such timber stands, which unfortunately appear to be fairly common, can not be taken care of by any reasonable diameter limit. The trees of desirable sizes simply are not on the ground to leave. The only alternative to insure restocking is to leave some larger trees to reseed areas where no small trees are available. A total volume of 1,000 to 1,500 board feet per acre (including the small trees present) will usually be sufficient.

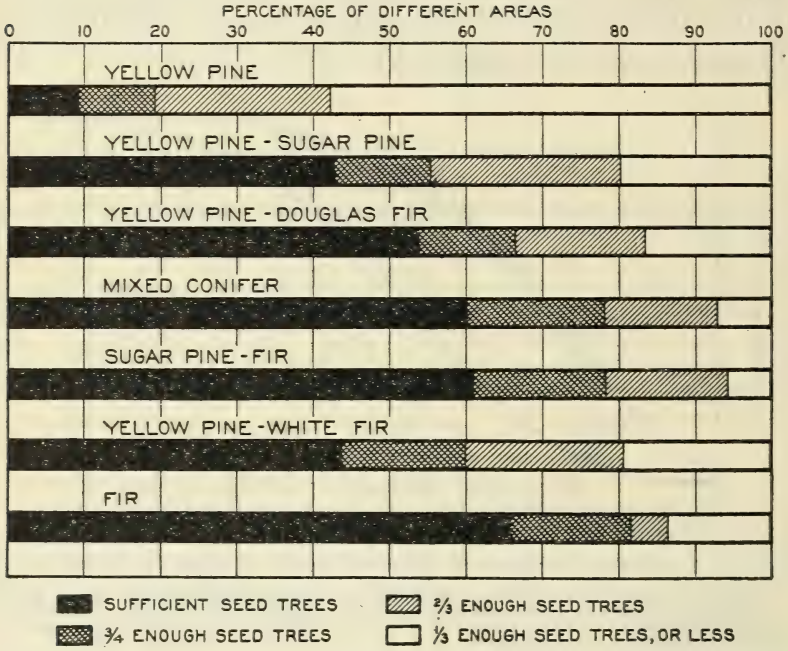

FIG. 18.—Percentage of areas in the important timber types fully supplied with seed trees, and those inadequately supplied. An area with 1 seed tree per acre is characterized as one-third supplied; with 2 trees per acre as two-thirds supplied; 3 as three-fourths; 4 or more as fully equipped. So classified, most of the areas examined in the different timber types are well provided for, having generally less than 20 per cent of area one-third equipped. Yellow pine, however, has as much as 58 per cent of area inadequately supplied. Cutting to the "seed tree limit" of 20 inches in diameter in yellow pine is not sufficient. Particularly under east-slope conditions it proves necessary to leave occasional large trees to supplement the smaller seed trees

The east side yellow pine type appears to be deficient to a varying degree in small seed trees. The stand data cited show certain areas well provided and others less than half supplied, assuming that the 4 small trees per acre basis is sound. It is safe to figure forties with 4 or more seed trees per acre as adequately provided, those with 3 trees as three-fourths provided, those with 2 trees, two-thirds, and those with 1 tree one-third. On this basis these two townships mentioned as deficient would be, respectively, 53.1 and 53.8 per cent stocked with seed trees if cut to a 20-inch diameter limit. (Fig. 18.)

MIXED TYPES

After an analysis of timber survey data for several townships, it was found that in progressing from the dry lower edge of the timber belt in the pure yellow pine type to the relatively moist fir types of the upper belt, the number of small seed trees gradually increased. (Fig. 19.) In the yellow pine type the average number of 18 and 20

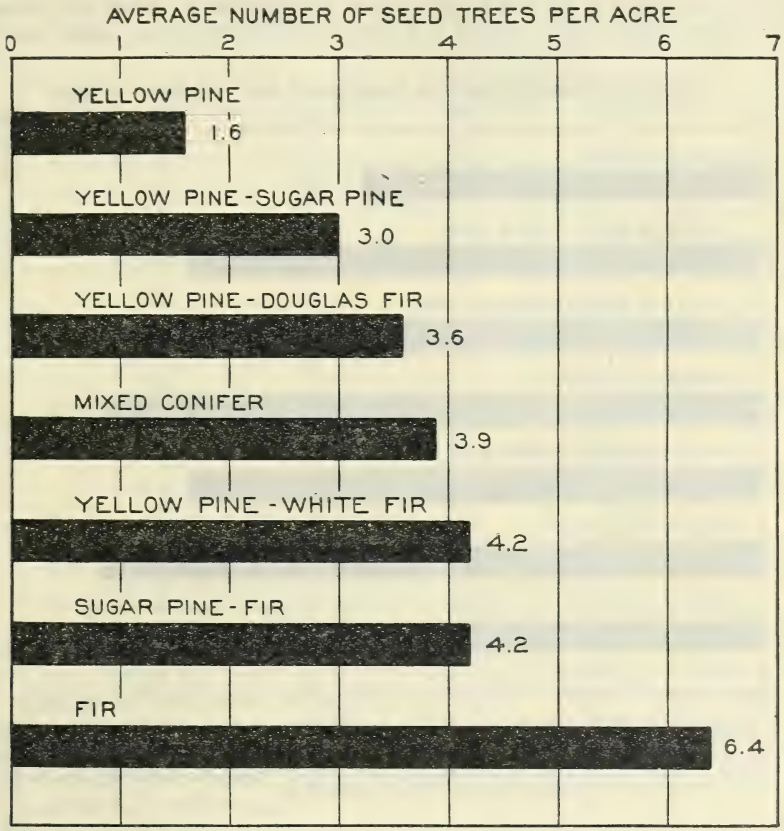

FIG. 19.—These are the trees 12 to 20 inches in diameter that would be left by the application of a 20-inch cutting limit in the important timber types. The significance of the averages given above is made clear in Figures 18 and 20

inch trees per acre is 1.6; in the yellow pine–sugar pine type, 3; in the yellow pine–Douglas fir type, 3.6; in the mixed conifer type, 3.9; in the sugar pine–fir, and also in the yellow pine–white fir types, 4.2; and in the group of fir types (white fir, white and red firs, and red fir), 6.4. If averages told the entire story, we might conclude that all types except the yellow pine are fairly adequately provided with seed trees. But it is worth while to go a step farther and examine, for the different important types, the percentage of all forties in each type with 1, 2, 3, 4, and more seed trees 18 and 20 inches per acre, as already described. This is because 6 or 8 seed trees per acre on one forty are of no avail on another forty with but 1 or 2 seed trees.

At one extreme is the yellow pine type with 53.8 per cent and 53.1 per cent of area provided for in the two cases analyzed. At the other extreme is the group of fir types with 89.7 per cent of the forties provided for and many with six or more seed trees per acre. Between these two come the yellow pine–sugar pine type and the yellow pine–white fir type with 76.3 per cent; yellow pine–Douglas fir with 81.5 per cent; mixed conifer with 87.9 per cent; and sugar pine–fir with 88.2 per cent. (Fig. 20.) For all except the pure yellow pine type, it appears therefore that there are on

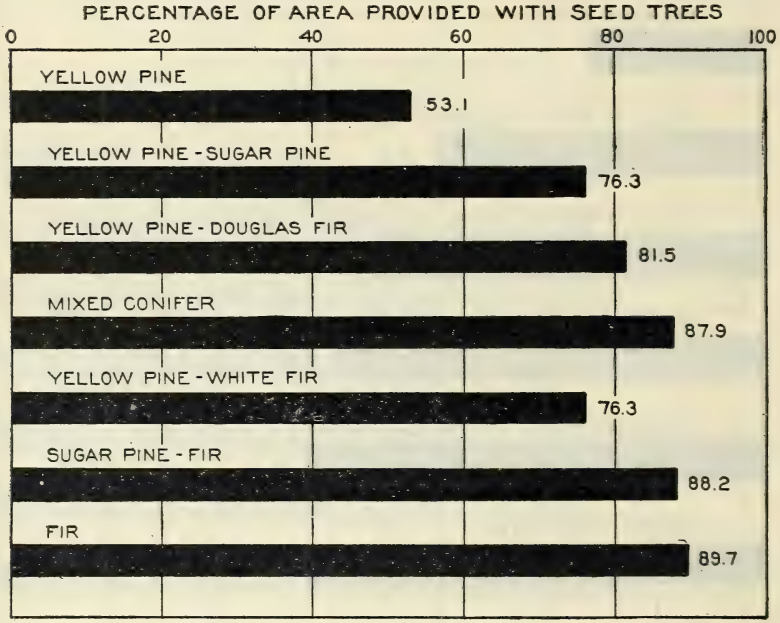

FIG. 20.—Average ability of various types to restock when cut to a 20-inch diameter limit. The inadequacy of restocking in the pure yellow pine type, with only 53.1 per cent of the area provided with seed trees, is in strong contrast with most of the other types. The bars also indicate the relative volume in trees over 20 inches in diameter that must be left to bring the different areas up to full production

the ground at the time of logging sufficient small seed trees 18 and 20 inches in diameter to restock at least three-fourths of the area.

Whether or not the 20-inch diameter limit method is the best means of insuring the restocking of cut-over lands, it is clear that it is a workable method.

THE STUMPAGE INVESTMENT IN SEED TREES

The investment in wood represented by the small trees left by cutting to a 20-inch diameter limit has already been indicated. It remains to be considered whether the money value represented by the small trees is actually obtained when the trees are logged, or whether it is not more profitable to the logging operator to leave the small trees on the ground.

THE REAL COST OF SEED TREES

Recent studies on the cost of log making, yarding, and manufacture of trees of different sizes have been made by Girard in Montana, and Bruce, Berry, Price, and Show in California. Bruce's conclusions (*5*) are that "it costs three times as much per thousand feet board measure to make logs from 18-inch as from 48-inch trees, and below that diameter the costs undoubtedly rise rapidly with each further decrease in size." The writer's conclusion, already stated in another connection (*13*), is that "even for 20-inch trees the cost per thousand feet of sawing is over twice what it is for large mature trees, and for the smaller trees the discrepancy is still greater."

The relative cost of yarding trees of different sizes has been studied by Price in connection with a comparative study of ground and high lead yarding, from data obtained on an efficient operation in the mixed conifer type. Trees were yarded as a unit to as large a size as possible. The data are summarized in Table 4.

TABLE 4.—*Effect of size of tree on cost of yarding*

Diameter breast high	Output per turn [1]	Diameter breast high	Output per turn [1]	Diameter breast high	Output per turn [1]
Inches	*Bd. ft.*	*Inches*	*Bd. ft.*	*Inches*	*Bd. ft.*
12	60	26	560	40	1,300
14	80	28	660	42	1,410
16	120	30	770	44	1,530
18	180	32	870	46	1,660
20	270	34	970	48	1,790
22	350	36	1,080	50	1,930
24	450	38	1,190		

[1] The "turn' is the round trip of the main line from the machine to the woods and return.

This shows cost in terms of output per turn. In general the time, and hence the crew cost, per turn is a constant, so that cost per thousand feet varies inversely as output. The average output for 18 and 20 inch trees is 225 board feet per turn. The average for 30-inch trees is 770 board feet, for 40-inch 1,300 board feet, and for 50-inch trees 1,930 board feet or, respectively, 3.4, 5.8, and 8.6 times as great as for small trees.

Bruce found on three operations (*6*) that "it costs from five to eight times as much per thousand board feet to yard logs from 18-inch as those from 48-inch trees, and that for trees below 18 inches in diameter the costs are undoubtedly even higher."

The yarding cost is an important element in the total cost of producing lumber. Without going into elaborate calculations it seems certain that small trees themselves are handled at a loss, and that by logging them the cost per thousand feet is raised for the entire stand. But even assuming that such trees have the same stumpage values as the average for the stand, the average investment per thousand feet of the total cut represented in leaving them standing will not ordinarily exceed 27 cents.

These studies at least raise the question whether after all the leaving of small trees for seeding purposes, as contemplated under a 20-inch diameter limit, will involve a serious additional cost to the operator.

THE STUMPAGE INVESTMENT IN THE YELLOW PINE TYPE, EAST SIDE

It has already been shown that in those stands in the east side yellow pine type which have sufficient trees up to 20 inches in diameter to insure restocking, the investment averages about 1,000 board feet per acre. In a representative township with but two 20-inch seed trees per acre, and the area consequently but two-thirds provided for, the stumpage investment is 700 board feet per acre. To provide adequately for restocking a total investment of about 1,000 board feet would be required. The average investment in trees under a 20-inch diameter limit for the various areas of the yellow pine type studied is 3.1 per cent of the total average stand of 18,000 per acre, or 560 board feet. As this is 53 per cent sufficient, a total of 1,050 board feet per acre is required. On the forties with a stand of over 20,000 feet per acre the investment is 480 board feet per acre, which is 53 per cent sufficient, making 950 board feet per acre requisite. On a national forest cutting with a selection of seed trees made regardless of diameter, the average is about 1,500 board feet and the volume most frequently left is 1,200 board feet per acre.

These instances point consistently to an average seed tree investment of 1,000 to 1,200 board feet per acre as sufficient to provide for the restocking of cut-over areas in the yellow pine type. It appears to be of little moment whether this volume is entirely in small trees up to the diameter limit of 20 inches, or whether, as on national forest cuttings, seed trees are selected for position. In general in this type some larger trees will be needed to supplement the trees caught under the 20-inch limit.

What is the net cash loss to the operator if this general average of 1,200 board feet per acre is left? With stumpage of western yellow pine worth $4 a thousand feet, the investment is $4.80 per acre or, with an average cut of 18,000 board feet, about 27 cents per thousand feet cut. But this is assuming the same net value for small timber as for large, whereas, it has just been shown that the "loss" in small timber left may actually be a net gain in lower logging cost per thousand feet of output.

THE INVESTMENT IN MIXED TYPES

A large body of data for the mixed conifer type, for different total stands per forty, and for all trees 12 to 20 inches in diameter, shows that the investment in seed trees ranges from 17,000 board feet per forty for the very open, non-merchantable stands, to 55,000 feet per forty for stands of over 40,000 feet per acre. A general average of 45,000 to 50,000 seems to be about right, or about 1,200 board feet per acre, as for the pine type.

Although the absolute quantity of lumber tied up in the small trees increases as the total stand increases, the percentage of the total volume represented drops. For merchantable stands (10,000 feet per acre or more) the maximum percentage is 7.5 and the minimum 3, with a general average of 5 to 6 per cent.

Figure 21, based on analyses of different types, gives an excellent summary by types of the average investment, both absolute and relative, that would be made under a 20-inch diameter limit on the best forties (those with a total stand of 20,000 feet per acre or

over). Considering all types, the total stand averages 1,140,000 feet to the forty, of which 41,000 feet, or but 3.6 per cent, is in small seed trees. This is only about 1,100 board feet an acre. Figure 21 shows what a small part of the entire stand this really is.

Although this investment is sometimes regarded as a serious obstacle, as a matter of fact many operators now using the high lead are dragging down or breaking off trees of the sizes needed and suitable for seed trees. Tallies of damage to small trees on two representative areas are summarized in Table 5. It is to be noted that about 3.5 seed trees (18–20 inches) per acre were destroyed by these logging methods.

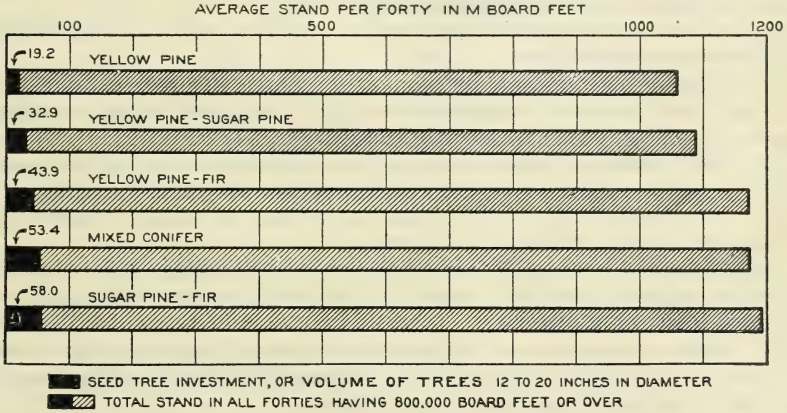

FIG. 21.—Board foot volume invested in seed trees on the best forties in five principal timber types. The average stand for these five types is 1,140,000 board feet to the forty and the average "investment" in 12 to 20 inch seed trees of the amount that would remain under a 20-inch cutting limit, is 41,000 feet, or but 3.6 per cent of the total. The relative sizes of solid and shaded bars in the diagram show the inconsiderable portion of the total stand required in the different types

TABLE 5.—*Effect of high-lead yarding on small trees*

Diameter breast high	Total trees per acre	Trees pulled down		Diameter breast high	Total trees per acre	Trees pulled down	
Inches	*Number*	*Number*	*Per cent*	*Inches*	*Number*	*Number*	*Per cent*
4	16.0	11.0	69	14	8.0	7.5	94
6	15.0	10.0	67	16	4.5	2.5	56
8	20.0	15.0	75	18	5.0	2.0	40
10	7.5	4.5	60	20	4.5	1.5	33
12	10.5	6.0	57				

It is further to be considered that the cost of making lumber from these small trees, if they are taken, is so great as to leave little or no margin of profit, nor is the lumber produced of a desirable quality. Of the total contents of trees 20 inches and smaller in diameter, a very low percentage is upper grade material. The usual profit in lumbering is obtained from the clear and shop lumber produced from the large trees, not in the common lumber sawn out of the smaller trees.

Cutting to a 20-inch diameter limit, if supplemented by occasional larger trees where needed, is recommended as an effective though

crude method of supplying seed trees. The proportionally small footage of 1,000 to 1,500 board feet per acre involved represents little real investment, and is greatly overweighed by the advantages to be gained.

GRAZING ON CUT-OVER LANDS

Grazing, like fire, is a factor which may work either to the improvement or damage of cut-over lands, but unlike fire it has been studied so little in a systematic way that few facts are available. In the Southwest Pearson (*11*) has studied intensively the effect of grazing on reproduction, and finds in many cases serious damage to the valuable advance reproduction.

Conditions noted by the examiners on cut-over lands in California may be summarized thus:

(1). Sheep grazing not infrequently results in serious damage to small size advance reproduction, by trampling and nipping, whereas cattle grazing apparently does little harm.

(2). Prevention of reproduction on certain cut-over lands abundantly supplied with seed trees is chargeable to sheep grazing.

(3). The percentage of the total cut-over area that is adversely affected by sheep grazing is unknown.

(4). Properly controlled grazing hastens breaking up of slash left after logging, and is a great aid in chopping up litter and facilitating control of fires.

(5). Many operators, as holdings of cut-over lands pile up, lease the grazing privilege at the highest obtainable figure, with the result that such lands are badly overgrazed.

(6). It is probable that, with proper management of stock, grazing of cut-over lands can be carried on with only minor damage to advance reproduction or delay in obtaining new reproduction; but the unrestricted lease system is bad in its effect on forest production.

Wherever the progress of reproduction after logging is found to be seriously retarded by grazing, effective remedial measures should be applied.

PROTECTION AGAINST FOREST INSECTS AND TREE DISEASES

Forest insects, particularly the tree-killing beetles of the genus *Dendroctonus*, are always present in both the virgin forest and on cut-over lands. Normally the loss caused to merchantable timber or to seed trees is such a small percentage of the total stand that active control measures are unwarranted.

At times, however, epidemic attacks develop over large areas, and cause really serious losses. Methods for controlling epidemics have been worked out by the Bureau of Entomology of the United States Department of Agriculture. Because of the mixed ownership of forest lands by the Federal Government, the State, and many individuals and corporations, an organized cooperative effort will be required to prevail against widespread epidemics. The machinery for such attacks should therefore be perfected, and made a part of the general protective system.

At present no tree-killing diseases are known to exist in the California pine region which can be directly controlled under prevailing economic conditions. In time the sugar pine may be attacked by the white pine blister rust, which is already present in the pines of the Northwest. If that transpires, organized effort, similar to that recommended for combating insects, will become necessary. The methods of control are being worked out by the forest pathologists of the Bureau of Plant Industry, United States Department of Agriculture.

THE RETURNS TO THE LANDOWNER

The forests obtained under the simple measures outlined above will not, in most cases, fully utilize the productive power of the land, for the design is primarily and above all to prevent forest destruction. With minor exceptions, however, forest lands so cut over and so protected will continue to produce commercial stands of timber, and lumbering operations so restricted will cease to create new brush fields or stands so seriously understocked as to be unmerchantable. The owner of the land will possess an asset rather than a liability.

The volume of wood produced will depend on the quality of the land as well as on the treatment of the forest. On good sites, a growth of 400 board feet an acre yearly may be expected, where young trees were abundant before logging. The rate will be lower on poor sites, though generally not less than 75 to 100 board feet. Part of this growth will take place on trees reserved under the diameter limit cutting as well as the occasional larger seed trees, but from two-thirds to three-fourths will be on the saplings and poles from 4 to 12 inches in diameter at the time of cutting. Thus a light second cut within 30 to 50 years will be possible on most lands, the exceptions being poor sites with scanty advance reproduction.

SUMMARY OF ESSENTIAL MEASURES

A restatement of the essential physical steps for keeping forest lands productive must include the following provisions:

SLASH DISPOSAL AND PROTECTION

Advance reproduction should be protected from fire before, during, and after logging. This can be accomplished by systematic protection of the virgin forest, no broadcast burning of the forest, care with and control of fire during logging, no broadcast burning of slash after logging, partial disposal of slash, and systematic patrol of cuttings for 8 to 12 years after logging.

LOGGING METHODS

Logging methods should not be such as to destroy advance reproduction more than absolutely necessary. Horse logging should be used on ground adapted to that type of logging, unless caterpillar logging proves as good or better both from cost and damage standpoints. High-lead yarding and the use of high-speed machines should be discontinued; ground or modified lead with low-speed machines leave the land productive.

INTENSITY OF CUTTING

Seed trees should be left for restocking the ground and as insurance against fire. Cutting to a diameter limit of 20 inches for all species should be practiced, involving an average investment of about 1,000 board feet per acre. On areas where insufficient small seed trees are present, additional larger trees should be left, at the rate of one per acre, and with an average total investment in such instances of usually not more than 1,500 board feet per acre.

COST

An attempt has been made to determine the additional costs involved in putting into effect the requirements outlined above. It appears that most of the steps proposed are neither revolutionary in character nor costly of application, and are justified in large measure by what good business practice demands.

The estimated cost (based on the experience of years) of fire protection measures per thousand board feet cut is made up of several items, as follows:

Partial disposal of slash on cleared lines	$0.10 to $0.12
Patrol during and after logging	.03 to .05
Falling snags	.02 to .03
Clearing around donkey settings and other systematic measures of care with fire	.02 to .03
General protection measures	.02 to .03
Total	.19 to .26

Against this must be balanced an equal or greater operating saving if fires are excluded and the necessity of suppressing large fires is eliminated.

Animal yarding on ground suited to its use, is about 50 cents per thousand feet cheaper than machine yarding, besides being less destructive to young growth and seed trees. No clear evidence points to the superior operating economy of the more destructive machine methods as compared with ground-lead yarding, and indeed on one operation studied the latter proved 11 per cent cheaper than the more destructive method of high-lead yarding.

That small trees up to at least 20 inches in diameter in the California pine region are usually handled at a distinct loss is indicated by various studies. Log making costs three times as much for small as for large trees; yarding from five to eight times; sawing at least twice as much. Trees up to about 20 inches in diameter seldom pay the cost of manufacture, are urgently needed as seed trees on cut-over areas, and would form the nucleus of a second cut.

THE PRACTICABILITY OF THE MEASURES PROPOSED

It is worth repeating that each of the steps proposed is in use by some operators, and that there is nothing theoretical or impractical about the measures. They have been proved by experience. The question is simply one of carrying them out systematically and consistently, without the omission of some essential step.

It seems fair to state as the major conclusion of this study, that the steps here proposed will work, that they can be carried out with slight changes in existing practice, and that they will involve but a trifling additional cost to operators. Whatever slight extra cost

may be involved is certainly of less consequence than fluctuations in price of lumber, loss due to poor equipment, or several other factors accepted as a part of the business risk in producing lumber.

Although these measures by no means represent all that can be accomplished to-day in the growing of timber in the California pine region, they bridge the gap between current practice, with a high percentage of denuded cut-over land or of broken and patchy stands, and a reasonable utilization of the land with the minimum change in existing practice and the minimum of extra logging costs. Whether the individual landowner plans to grow a new crop of wood or not, such utilization is believed essential in the public interest. It is essential likewise to the owner who proposes to exchange or sell his land to someone who will engage in timber growing.

The owner of forest land who wishes, however, to make full use of the growing power of his land as a business asset should carefully consider the adoption of other methods which are in general and successful use on national forest cuttings and which at a comparatively small additional cost will more nearly attain a complete utilization of the productive capacity of the land than will the foregoing minimum measures. Such methods, designed to insure full timber crops, are discussed in the following pages.

MEASURES NECESSARY TO PRODUCE FULL TIMBER CROPS

CONDITIONS AFFECTING PRIVATE TIMBER GROWING

It is customary to discuss private timber growing in California pine on the assumption that because it takes 75 or 100 years to grow a merchantable tree, it will be necessary to wait for a couple of generations after the virgin forest is cut before any returns begin from investments in a new timber crop. With this erroneous assumption as a start, and with its corollary of repeated administration and protection expenses piling up, private timber growing appears to be indeed a hopeless undertaking. Compound interest calculations become the controlling factor.

The real facts of the matter are, it would seem, sufficiently clear. Actually, for any landowner, private or public, the situation is this, starting for the sake of simplicity with a new operation on a good quality site:

The first year, say that one-thirtieth of the entire holding is cut over. Certain expenses have to be incurred that year to protect and carry the operation as a whole. Taxes must be paid, fire protection must be given. The cut-over land must be protected as an integral part of the entire operation, not as a separate and distinct entity. The owner's real financial problem is to show a net operating profit. The second year the situation is still substantially the same; current expenses are for the protection of his operation, not for any particular part of it. Essentially it makes no immediate financial difference whether his cut-over land is a brush field or is growing timber.

No business man would propose that current expenses such as these should be entered on the books and carried forward year

after year at compound interest. The case is exactly the same as rent and taxes on a store. Necessary current costs for doing business are always wiped off the books annually. No storekeeper could possibly justify continuing in business if each year he entered his protection and administration expenses and compounded interest on them. The yearly net operating profit is the sole criterion of the success of the business.

In the thirtieth year of the operation, when the last of the virgin timber is cut, there still exists the same necessity as in the first year for certain current expenses to protect the operation as a whole, and this has been true in every year. Unless the operator had made profit year by year, or at least more frequently than he lost, he would not have continued in business. In other words, expenses on his cutover lands, which now make up 100 per cent of his holdings, have been met currently, and it is clear that these lands have no accumulated compound interest on them. The current expenses incurred have been necessary to continue in business and have been wiped out currently.

Now, with the virgin timber gone, the condition of the cut-over lands determines the future of the owner's business. Unless they have been kept productive the operator must forthwith go out of business. If they have been carefully handled, the operation can start all over again and go through a second cutting cycle.

The financial loss to the owner of dismantling a going business is too little considered; no possible argument can demonstrate that the forest owner who must go out of business is as well off as one who can continue his operation on second growth.

With existing forest conditions in the California pine region, and under the partial cutting plan to be discussed as necessary to obtain full timber crops, a second cut on any site can be made within 30 to 50 years after logging the virgin forest, although it takes 75 to 100 years to grow merchantable trees from seed. This is possible because of the presence of young growth and small thrifty trees of merchantable size, which are reserved at the time of the first cut and grow rapidly thereafter.

The number of years before a second cut can be made will naturally vary. On the best quality lands, where trees grow rapidly and where considerable young growth can be left at the time of the first cut, 30 years will be ample. On poorer sites, and where fewer thrifty young trees are available to leave, the period between cuts may be as high as 50 years.

Occasionally areas will be found where so few thrifty trees are available that clear cutting is the only recourse, leaving only enough trees for seeding. Where this is necessary, the second cut will obviously be light; but fortunately forests with a dearth of thrifty trees are usually mixed in with more extensive, well supplied areas. A few clear cuttings will not therefore prevent an early second cut on the operation as a whole.

PREREQUISITE CONDITIONS

Essentially, measures that insure full timber crops will be part and parcel of a going operation and must be carried out at the time of logging. The forest owner in the California pine region who commands a reserve of virgin stumpage sufficient to run his mill for 30

to 50 years is in the best possible position to obtain full timber crops. He is then certain to remain in the lumber-producing business for several decades, and as his virgin stumpage approaches exhaustion, more and more he will be in the cut-over land business. If his lands are of generally good quality, they can be made to grow timber rapidly enough so that when the virgin forest is gone a new crop of wood will be ready.

The owner of extensive forests has an opportunity to grow wood on a commercial basis by utilizing as fully as possible the productive power of his cut-over lands. Such simple measures as those discussed in the first section of this bulletin will prevent forest detruction and will give the owner some real values to be used in selling or trading his land. But if he is to remain in the lumber business permanently and plans to utilize cut-over land as part of the operation, obviously the most profitable management will be that which produces the maximum stand possible at a reasonable present outlay.

This section of the bulletin, therefore, aims to present what is now known regarding the best method of accomplishing this end, under present conditions.

The practices developed in national forest cuttings are the principal basis for the discussion that follows, since it is on these forest properties that the most intensive effort has been devoted to obtaining full production.

IMPORTANCE OF SITE

The productive power of forest land, spoken of as quality of site, varies tremendously, and site must always be taken into account in deciding on the practice for any particular area. The most workable method of determining site quality is by the average maximum height of mature trees. If, for example, the average tallest mature trees show a height of over 150 feet, the site quality may be considered good; if under 125 feet, poor; and if 125 to 150 feet, medium. On good sites, as already noted, a rate of volume growth of at least 3 per cent per year can be obtained on properly selected trees after cutting, whereas on poor sites the rate is lower.

The owner of forest lands of generally good quality can be sure that a good rate of growth will be made by young thrifty trees left in logging in any number up to a minimum of 6,000 to 10,000 board feet per acre. Even trees intermediate in character between blackjacks and yellow pines will make profitable growth. This volume of timber will not seriously interfere with the rapid development of small reproduction, which will in turn furnish the third cut on the area.

THE GROWTH OF TIMBER IN THE PINE REGION

The actual yield of timber obtained from a particular area will depend on a variety of factors. All that can be done here is to indicate the range of possibilities as determined by investigations over a period of years.

With the partial cutting method to be discussed, a reserve of trees now over 12 inches in diameter will be kept for increased growth and these will serve both as seed trees and as a basis of a second cut. For good, medium, and poor sites this reserve will average 5,000, 4,000, and 3,000 board feet per acre. In a period of 30 years after logging, these trees will increase to 12,500, 8,000, and 4,500 feet per acre, respectively.

The most important source of new growth on cut-over lands lies in the small trees below 12 inches in diameter at the time of cutting. On good sites with well-distributed advance reproduction, of which two-thirds is saved during logging, the growth in a 30-year period will amount to between 9,000 and 10,000 feet per acre. On medium and poor sites the growth on this class of material will be around 6,000 and 3,000, respectively.

The total growth to be expected with good practice varies from 150 board feet an acre each year to 500 or 600, depending primarily on site, thus exceeding by about 50 per cent the growth under the minimum timber-growing measures discussed in the first part of this bulletin. At an average stumpage rate of only $3 per thousand feet board measure, the value of the annual increment will range from $0.45 to $1.80 per acre. In addition, the volume of merchantable timber reserved is to be counted on, and this will naturally be of a higher quality in the future than it is at the time of the first cutting. In short, attainable growth to-day in the pine region is sufficient to justify commercial timber growing when carried on as part of a going operation.

Nearly every extensive area of timberland will contain a wide range of site quality, varying often from the best to inferior lands. Holdings on which the land is predominately good, even with small areas of poor lands, offer naturally the best opportunity for the growing of timber. It is estimated that in the pine region as a whole not over 20 per cent of the private forest lands are of a poor site quality, and the great bulk of these are on the east slope of the Sierras.

The great advantage of the partial cutting plan proposed is obviously that it makes possible a second cut within one-third to one-half of the number of years required to grow a merchantable tree from seed.

Even the rapid growth under partial cutting does not represent the full productive capacity of the land. On the west slopes of the Sierras, full stands of even-aged young timber produce in a period of 80 years, 80,000 board feet per acre on good sites, 50,000 on medium, and 30,000 on poor sites as measured by the international log rule. On the east slope of the Sierras, with a rotation of 120 years, the yields for the same three classes of land are 83,000, 55,000, and 27,000 board feet, respectively. The longer period required to grow merchantable timber makes it particularly important on the east slope to save the advance reproduction, which already has a good start, rather than to wait for new seedlings to come in and go through a period of very slow juvenile growth.

Until planting becomes possible these figures can not be attained on large areas; they indicate the rapid growth possible, especially on the better lands. As more and more intensive measures become possible, growth can be still further increased.

BASIC PRINCIPLES OF FULL TIMBER CROP PRODUCTION

The decision to grow full timber crops for future cuttings is one that must be made in advance of logging. However simple and alluring it may seem to substitute planting for the advance reproduction and seed tree plan, the latter under present conditions is

by far the safer and more economical way of keeping forest lands productive. The owner of forest lands whose property is mostly in virgin forest is in the best position to undertake timber growing. At low initial expense he can leave the land highly productive after the first partial cutting, and within a few decades can obtain a second cut from the rapidly-growing young reserved trees. Even the third cut, which will come principally from the smaller advance reproduction, is already on the ground, requiring only care in logging, proper slash disposal, and protection from fire for its maturity.

Restoration of a forest after destructive lumbering, on the contrary, requires not only the large expense of planting, but also the inevitable period of slow juvenile growth, which natural reproduction left after logging has largely passed through. Further, planted forests will probably yield a cut only at the end of the full rotation (unless thinning becomes possible) and the operator will not have a second cut, as on conservatively logged lands, to tide over the period between the end of his virgin timber and the merchantability of trees that are now very small or nonexistent.

Essentially, then, the decision for full timber crops, like the choice of minimum measures to maintain partially productive lands, must rest on what is done at the time of logging.

The additional measures then taken for the maintenance of full timber crops are, simply expressed, a form of partial or selective cutting. The underlying principle is that young and thrifty trees will grow rapidly after logging, and will produce future profits greater than if they were cut now. The forest-land owner by reserving such trees, provides definitely for the second cut, besides providing for rapid restocking of blank spots.

Thus, the fundamental conditions to be met in carrying out the partial cutting plan and thereby obtaining rapid and profitable growth on cut-over lands are: (1) To combine in the trees selected for leaving the highest possible qualities of growth and seed production. (2) To remove all mature, decadent, malformed, or diseased trees, and to leave only thrifty sound trees with capacity for rapid growth. (3) To leave sufficient trees for seed production to insure restocking of land and to maintain the pines in the new stand. (4) To preserve during logging the advance reproduction and the reserved trees. (5) To control the danger to reproduction and seed trees from fire. All these objects must of course be attained while making the operation a profitable one for the logger.

Essentially, the methods worked out on national forests and used as the basis for desirable forest practice for private owners aim first of all, while making the logging profitable, to improve the condition of the forest; and second, to leave a nucleus of trees now of merchantable or near merchantable sizes that will restock the area, will make rapid growth after logging, and will form the basis of a second cut in 30 to 50 years. Within three to five decades restocking will be completed; complete release of the principal part of the stand (advance and subsequent reproduction) will be needed; and the rate of growth on the reserved trees will doubtless have become low. Most private owners will have utilized their virgin timber in that length of time and, in order to continue in the business, must start going over their lands the second time.

Though reservation of trees as a basis for a second cut is good silviculture and good management, where continuity of operation is desired, certain forms of it are questionable.

The cutting of pine only from mixed stands of pine and fir is a practice of dubious value. Although with present markets it is often difficult to sell the firs (especially white fir) at a profit, to leave them all is likely to reduce seriously the income from the second and third cuts. The question really concerns principally the very old, large, and defective white firs, which often are mere shells of sound wood. Leaving thrifty sound fir up to a diameter of 24 or even 30 inches is good practice.

If the defective veterans are left, it should be with a clear understanding that deterioration will continue, for the tendency will be for rot to destroy the valuable heartwood more rapidly than new wood is formed. Thus net loss rather than growth is to be anticipated in this class of trees, even if they survive. They are as valuable now as they are ever likely to be. Moreover, death from wind throw, wind breakage, and insects is ordinarily high where large firs are left standing, resulting in loss of some valuable material and increase in the fire hazard. It is decidedly desirable to cut and utilize the veterans at the time of logging.

The principal drawback to leaving the old white fir is, however, not so much the fate of the trees themselves as it is the hampering influence they exert on the young and thrifty portion of the new forest. The large trees are certain to reduce greatly the growth rate, particularly of seedlings and saplings—the basis of the third cut; and also of trees already of merchantable size—the basis for the second cut. Furthermore, the space occupied by the decadent veterans themselves is not available for thrifty growing stock. The owner looking forward to future crops can ill afford to reduce his profits in this fashion.

Even if a large quantity of thrifty fir is left—which can well be done, since such trees after logging grow at a rate higher than that of yellow pine and only equaled by sugar pine—it is desirable to leave pine seed trees. Pine reproduces more rapidly on cut-over lands than does fir, and is thus needed to complete the new forests. The value of the pines will undoubtedly continue high.

The problem of defective fir in present-day cutting is thus a perplexing one. If logging and manufacturing costs will clearly not be repaid by the selling price, the next best course is to fell the trees and leave them in the woods. This will not ordinarily represent a heavy outlay, and is advisable for the owner with a settled land policy. The cost is certain to be more than repaid by increased growth on the thrifty trees in the stand.

The conclusions stated and practices recommended are based on the wide experience of the Forest Service in the California pine region and on a very large amount of research work in methods of cutting that combine the various major objectives. In this connection it is unnecessary to discuss again the importance of timber types. The virgin forest is so variable that hard and fast rules, specifying the exact treatment for each type, are generally worthless, and if followed literally lead to poor practice, particularly in reserving trees. The plan of this discussion is therefore to present principles

and generalized rules for desirable practice, based on research and experience, and to specify in detail only those practices which properly can be so stated.

The principal factors are fire protection and slash disposal, logging methods, and intensity of cutting. Each of these will be treated separately.

SLASH DISPOSAL AND FIRE PROTECTION

The essential slash-disposal and fire-protection measures required to keep forest lands productive have been discussed in the first section of this bulletin. An adequate general protection system, care with fire, and special protection measures and patrol are, of course, equally needed on lands managed for full timber crops.

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FIG. 22.—SLASH PROPERLY PILED READY FOR BURNING

When slash is well piled, damage to young growth and seed trees is largely avoided. Compact piles located away from the remaining trees and young growth accomplish this.

Partial disposal of logging slash plus patrol, with the object of minimizing fire danger, was recommended for owners who had not fully decided on deliberate growing of timber, and whose primary interest was to keep the lands valuable for sale or exchange. To such owners the immediate cost of piling and burning, mentioned as a desirable and effective means of reducing hazard, is likely to be a deterrent, because it is not certain that this cash investment can always be recovered in sale or exchange. But once a land policy of timber growing is decided on, additional measures for protecting the investment can and should be adopted. Under these circumstances, pending further study of the partial disposal plan, piling and burning of the slash is recommended as a superior method.

PILING AND BURNING

By the method of slash disposal used by the Forest Service in California and generally known as piling and burning, the slash is piled as logging progresses, and all or part of the piles are burned at a season of the year, usually late fall, when fire will not spread in the litter. Constant study and practice by many men over a long period of years have developed the technique of this method to a high point, and in actual practice under close supervision results are generally good. Properly used, the system cleans up 75 to 90 per cent of the slash with only a small percentage of damage to advance reproduction and seed trees. (Fig. 22.)

Instructions to Brush Pilers on National Forest Timber Sales

1. Axes and pitchforks are the best tools for brush piling.

2. Limb all tops.

3. All brush should be piled in tepee-shaped piles with the large limbs up to 4 inches in diameter on the outside. Larger limbs should be left out of the piles. Do not pile it in windrows, or it will have to be repiled.

4. Piles should be 5 to 7 feet across and 4 to 6 feet high. Larger piles may be made in large openings and smaller piles in small openings.

5. Build piles compactly so that they will shed rain and snow and will burn readily after storms.

6. Keep the piles well away from green timber and young growth (15 feet away if possible).

7. Pile no brush on dead and down timber.

8. Pile oak, manzanita, and young trees destroyed in logging with the other brush.

9. If you do not understand these instructions ask the forest officer in charge of the sale. It is his business to show you how to do this work.

That skill and care must be exercised in the employment of the method has been demonstrated repeatedly, on both national forest and private lands. Without entering into a lengthy dissertation on the inherent dangers, the principal points of failure may be pointed out. The object of the practice is of course to reduce fire hazard and still preserve the advance reproduction and seed trees after logging.

SOURCES OF DANGER

(1) Misjudging conditions and burning at a time when the fire will spread. Result, wiping out or seriously damaging advance reproduction and seed trees.

(2) Sudden change in weather while burning is in progress, so that fires spread before they can be stopped. Result, same as 1. Or heavy rain or snow in the first fall storm postpones burning until a season when slash is more difficult to burn.

(3) Touching off too many near-by piles at one time. Result, drying out of litter and the spread of fires.

(4) Poor location of piles, mixed in with advance reproduction, instead of being placed in open spots or on skid trails. This is almost certain to happen without close supervision. Result, piles must be either left or repiled or, if they are burned, advance reproduction is destroyed.

(5) Making piles too large or too small or careless piling, resulting in any case in serious damage to advance reproduction.

(6) Letting piling get behind logging to such an extent that the slash dries out and is hard to pile and the leaves and twigs fall off.

At its best, as illustrated on many national forest cutting areas, piling and burning results in an excellent clean-up of the cut-over

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FIG. 23.—POOR SLASH PILING IS EQUIVALENT TO BROADCAST BURNING

With small, loose piles of slash, heaped up without regard for remaining growth, the expense of piling is considerable, and the result is equivalent to a broadcast burn. Reasonable care will prevent this destruction.

lands, with slight damage to reproduction. At its worst, as illustrated particularly on certain private lands where slash has been piled and burned by contract, it approximates broadcast burning in its effect. (Fig. 23.)

ADVANTAGES

Studies on national forest cutting areas where a good job of piling and burning has been done, show that 6 to 17 per cent of the total ground area is covered by the burned slash piles, depending on the density of stand and volume of timber cut. By proper location of the piles in skidding trails and in natural openings, the damage to young growth can be practically eliminated. Scattered as the burned spots are, under the best practice, they offer little more opposition to full timber production than do the loose bowlders found in many thickly forested regions.

The desirability of piling and burning, carefully done, is beyond question. It is the most that can be done under present conditions in reducing inflammable material. Experience shows that fires on cut-over areas where slash has been disposed of are not greatly more difficult to control than in virgin forest, and areas on which slash has been piled and burned have seldom been burned over after logging. On the basis of experience to date, piling and burning, though costing from 40 to 50 cents per thousand feet of lumber, is known to be a success, and deserves the preference over other methods of slash disposal, where maximum yield in second growth is

the owner's aim. Leaving of slash, under intensive patrol, has not yet this recommendation, but is a possible substitute well worthy of further study and test.

Even with piling and burning, systematic fire protection of all lands remains the key to growing timber. Besides piling and burning slash, it will be found desirable to fall snags on all cutting areas. The trifling cost per thousand feet cut is more than repaid by the greater ease and certainty of stopping fires if no snags are present to aid in spreading the fires by spotting.

COST OF SLASH DISPOSAL AND SPECIAL FIRE PROTECTION

The various practices that have been recommended entail direct costs per thousand feet cut, varying from low to high as follows:

Piling and burning slash	$0.40 to $0.50
Clearing around donkey settings	.02 to .03
Falling snags	.03 to .08
Special patrol after logging	.03 to .05
General protection measures	.02 to .03
Total	.50 to .69

Against these costs must be balanced the saving of suppression costs on large fires, which on one large operation amounted to 21 cents per thousand; also the loss of equipment and merchantable stumpage, and loss due to shutdown of operations, the values for which are unknown. Because of the greater productiveness of the lands, systematic reduction of hazard by piling and burning and protection of cut-over lands are good business practice for the owner who is growing timber.

PROTECTION AGAINST INSECTS AND DISEASES

In addition to fire-protection measures, provision should be made for treatment of forest insects and diseases. The methods for controlling tree-killing beetles, particularly those of the genus *Dendroctonus*, are being worked out by the Bureau of Entomology of the United States Department of Agriculture. Control measures should be used as recommended.

The control of the important wood-destroying fungi and other diseases can, under present economic conditions, best be approached through cutting the diseased trees at the time each area is logged.

If the white pine blister rust becomes established in the sugar pine, special measures will be necessary to prevent serious loss of this most valuable species. Under such circumstances the advice of the forest pathologists of the Bureau of Plant Industry, United States Department of Agriculture, should be the guide.

METHODS OF LOGGING

Damage to advance growth is inevitable in logging the forests in the California pine region; but, as has been seen, the serious loss of seed trees that occurs with high-lead and high-speed logging is not necessary to the profitable exploitation of forests. The measures already discussed aim to preserve at least 50 per cent of the young growth, with the least alteration in existing practices.

The operator engaged in growing timber will be interested in increasing this percentage as much as possible and will desire to minimize logging damage. He can with profit employ measures that have proved valuable on national forest cuttings, in addition to those proposed in the first part of this bulletin.

ADDITIONAL MEASURES TO INSURE BEST TIMBER GROWTH

These additional measures concern chiefly the regulation of donkey yarding. By placing blocks and using shear trees to avoid pulling through areas of established young growth or reserved trees, by placing main lines so that they will not slash around and damage or kill reserved trees, it is possible to increase materially the quantity of reproduction saved. On national forest cuttings where these precautions are exercised in yarding, about 36 per cent of the advance reproduction is destroyed and 7 per cent of the seed trees scarred, but not killed. On private lands the corresponding average losses are 53 per cent and 12 to 20 per cent. The results on national forest cuttings do not involve a material increase in logging cost, and show what can be done if preservation of reproduction is an object.

One other feature of logging requires mention. Lack of care in falling timber ordinarily breaks off or injures the crowns of part of the reserved trees, and always destroys a part of the advance reproduction. It has been estimated by Birch that the extra cost in falling on national forests amounts to only 1 cent per thousand feet cut, and it is only necessary to compare typical national forest and private cuttings to realize that this trifling expenditure means a real difference in the condition of cut-over lands.

The experience of the past decade or more in logging national forest timber shows convincingly that the reduction of damage from various sources is neither impossible nor costly. As the various steps, such as care in felling and in yarding, are actually put into practice, it becomes more and more evident that very slight rearrangement of logging plans and practice makes all the difference between leaving the cut-over land in excellent or in only tolerable condition.

Studies of extra costs of logging national forest stumpage (*4*) indicate that the cost due to care in yarding and in falling timber to avoid small trees and reproduction amounts to about 7 cents per thousand feet.

The forest owner interested in building up his forest and capitalizing the opportunities for profitable growth will find his constructive effort centered largely on selection of trees to leave. Proper cutting methods, which leave on the ground an adequate number of effective seed trees and thrifty trees capable of rapid growth, constitute the chief factor in making timber growing most profitable. Fire protection, slash disposal, and logging restrictions, important as they are, primarily aim merely to prevent denudation.

ADDITIONAL MEASURES IN CUTTING PRACTICE

The simple cutting measures discussed in the first part of this bulletin do not approach the standard maintained on the national forests. They provide merely for an adequate number of small

seed trees selected mechanically through the device of a diameter limit, supplemented by occasional larger trees. Cutting to a diameter limit does fairly well in obtaining good distribution of trees, but catches some poorly formed, old, and suppressed trees, misses some fine thrifty young individuals, and on part of any cut-over area leaves openings with no trees.

Better practice for producing full timber crops must depend on individual selection of trees to be left. It must, moreover, be based on the same treatment of all species found in virgin forests; and on the selection of reserved trees primarily on the characteristics of the individual trees. Three seed trees per acre, carefully selected, will be at least as effective as four per acre mechanically selected by diameter-limit cutting.

The most rapid growth and most effective seeding will be obtained when the reserved trees are selected and marked by a forester or experienced woodsman, familiar both with logging requirements and the characteristics of desirable trees.

SELECTION OF SEED TREES

As already noted, a "seed tree" is a healthy, uninjured tree of over 18 inches diameter; that is, of a size that can be counted on to produce seed immediately after the area has been logged. As size increases cone production per tree also increases, a 26-inch tree producing, on the average, about three times as many cones as an 18-inch tree, though at greater cost in board feet per thousand seeds.

A study in Arizona (*10*) showed clearly that the germination percentage of seed from blackjack trees was uniformly higher than that from the older yellow pines, and that for trees of the same size the blackjack produced more seed than the yellow pine. Therefore, for seed production, as well as for rapid growth, thrifty young trees should be reserved wherever available.

Where no thrifty young seed trees are present, intermediate trees or, very occasionally, typical mature pines must be kept. Similar conclusions apply to other species, though much less study has been devoted to sugar pine and the firs than to yellow pine.

NUMBER OF SEED TREES REQUIRED

Study of carefully marked national forest cuttings in different types makes it fairly certain, as shown on page 40, that an average of three seed trees per acre, carefully selected, both for their individual characteristics and their distribution, will be sufficient for restocking.

As shown also, the number of young and thrifty trees present is smaller in the East Side yellow pine type than in most other timber types, including the mixtures of yellow and sugar pines, Douglas and white firs, or any two or three of them. On national forest cuttings, in mixed types, as many as 20 or 25 thrifty young trees per acre are left after cutting, the great majority of which are reserved for growth, not for seed production.

In the great majority of cases thrifty trees selected for growth will serve also as seeders. Only in case no such trees are available on a particular area will it be necesary to reserve trees solely for seeding purposes.

DISTRIBUTION OF SEED TREES

The distribution of seed trees is of fundamental importance. If the production of full timber crops is desired, no mechanical method of selecting the trees or of spacing them is generally applicable.

Obviously the statement that three seed trees per acre are needed does not imply that this number will appear on each acre. The virgin forest is so variable that in following out the principles here laid down it is often necessary to make openings of 2 or even 3 acres in extent, simply because there are no suitable trees to leave. An occasional opening of 3 acres is not to be regarded too seriously, particularly if there are seed trees around the edges. For any extensive area, however, an average of three trees per acre should be left.

SELECTION OF TREES TO LEAVE FOR GROWTH

Full timber-crop production does not stop with the selection of three healthy seed trees to the acre. It demands as well the reservation of other thrifty trees capable of rapid growth after release by cutting. Such trees will be the basis for the second cut, and their selection is the key step distinguishing this type of forest cultivation from the measures previously discussed.

Trees of certain characteristics make rapid growth after release by cutting, and others have no marked capacity for profitable growth. In general, young trees are thrifty; old trees are growing so slowly that though they may respond to cutting the rate of growth is still very low. The external physical marks of youth are; first, the bark, which, particularly in the pine, is dark in color and broken into finer corrugations than on old trees; second, form and shape of crown. Uninjured young trees have conical pointed crowns, the unfailing indication that height growth is in progress. Usually young trees have long crowns, i. e., more than half the total height of the trees. Lumbermen recognize that the young trees, variously called "blackjack" or "bull" pine, yield a poorer quality of lumber than is obtained from the mature or "yellow" pines. Thus, saving young trees for growth and for seeding may not affect seriously the profitability of the logging operation.

Flat or rounded tops, especially the former, are the unfailing indices of old age, and show that height growth has ceased or is at a very low ebb. Cessation of height growth is correlated with great reduction in the rate of diameter growth and with loss of ability to attain a profitable acceleration in growth rate after release. Therefore, the primary rule in selecting trees to leave for growth is to reserve healthy trees of "blackjack" characteristics and to cut "yellow" pines. With the other important species, similar practices should be adopted, cutting the old and leaving the thrifty young trees.

INCREASED GROWTH ON RESERVED TREES AFTER CUTTING

By careful selection of trees to remain uncut, rapid and profitable formation of wood can be obtained. This is one of the important sources of value of properly logged lands, and is largely or entirely lost through unregulated logging.

The rate of increase of growth after cutting varies greatly, depending on the amount of cutting close to the trees left, the character of the reserved trees, and the quality of the land.

Response to cutting is more prompt, longer sustained, and greater on good than on poor sites. The increased percentage may be 100 or more if the trees left are well selected and well spaced.

The attainable growth on reserved trees for different qualities of soil is well illustrated in Table 6, which is based on data obtained from permanent sample plots.

TABLE 6.—*Percentage of average annual basal area growth of yellow pine for 10 years after cutting*[1]

Basic data			Growth, by inch diameter classes		
Site	National forest	Number of trees	12–17	18–23	24–29
			Per cent	*Per cent*	*Per cent*
III	Shasta	288	0.78	0.62	0.45
III	Tahoe	261	1.35	.90	.67
II−	Plumas	306	1.52	.98	.70
II+	Stanislaus	160	2.69	1.61	1.29
I	Sierra	33	3.27	3.00	.78
I	Sequoia	76	4.72	4.21	2.75

[1] Basal area signifies cross-section area of trees at 4.5 feet from the ground.

On the better sites a rate of growth of 3 to 4.75 per cent is obtained on trees up to 24 inches in diameter, whereas on trees from 24 to 30 inches the rate falls to 2.75 per cent. On medium and poor sites the rate is still lower. These figures are conservative, since volume growth rate is always greater than basal area growth rate, on trees that are making height growth. Thrifty young trees of the type reserved under desirable forest practice would certainly exceed the rates above indicated.

RELATIVE GROWTH RATE OF DIFFERENT SPECIES

The same studies have also given an excellent basis for determining the relative growth possibilities of the principal tree species. On medium sites, for trees 18 to 24 inches in diameter, the relations between annual basal area growth percentages are indicated in Table 7.

TABLE 7.—*Comparative growth rate of different species, medium sites*

Species	Annual growth	Trees
	Per cent	*Number*
White fir	2.22	463
Sugar pine	2.07	81
Yellow pine	1.50	156
Incense cedar	1.21	321

Considering rate of growth, sugar pine is a better tree to leave than yellow pine, and it also maintains a good rate of increment to a higher diameter than any other species. White fir, because of its high growth rate is, where sound, a desirable species to leave.

Douglas fir appears to fall between yellow and sugar pines, though this species has not been so thoroughly studied as the others.

The highest yields and highest rate of growth after logging can be looked for in the sugar pine–white fir type, which is on the best sites and has the two species with the greatest potentiality for growth. The only requisite is that the timber be cut rationally, especially that decadent and defective white firs be removed.

Two controllable factors influence to a pronounced degree the rate of growth attained after logging. These are the crown characteristics of the trees and their distribution.

INFLUENCE OF CROWN FORM ON GROWTH RATE

The importance of selecting trees with good crowns is well illustrated in Table 8, which uses yellow pine 12 to 30 inches in diameter to illustrate the annual growth rate percentage, for trees with crowns making up different proportions of the total height of tree.

TABLE 8.—*Relation of crown length to rate of growth in basal area of yellow pine*[1]

Crown length on the basis of total height of tree	Yearly growth for three sites			Crown length on the basis of total height of tree	Yearly growth for three sites		
	Site I	Site II	Site III		Site I	Site II	Site III
Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
30	1.40	0.40	0.40	60	2.40	1.01	0.55
40	1.50	.50	.40	70	3.60	1.70	.80
50	1.75	.65	.45	80	4.90	2.50	1.20

[1] Basis, 434 trees curved.

As the relative length of the crown increases, the trees show more and more rapid growth. Naturally, the better the quality of the land, the higher is the growth rate, though the influence of crown length is important on all the sites studied.

For yellow pine about 60 per cent of the total height is the most desirable proportion of crown for trees of the size usually reserved; trees with longer crowns are scarce in the forest and make little clear lumber.

On an area of medium-quality forest, the trees of a given size were classed in two groups, the first composed of trees with crowns of average or larger size and pointed tops, the second with smaller than average crowns and round, flat, or dead tops. It was found that the trees of the first group were growing at a rate of 1.22 per cent annually in basal area, while those of the second group were growing at a rate of only 0.42 per cent annually.

EFFECT OF DISTRIBUTION OF TREES ON GROWTH RATE

Study of trees on cut-over areas shows clearly that to obtain the maximum response to cutting, trees must be released, and that trees left in groups do not respond. This is well illustrated in Table 9.

TABLE 9.—*Effect of grouping on growth before and after cutting in yellow pine, Stanislaus National Forest*

Number of trees	Treatment	Annual growth				Average increase or decrease
		Before cutting		After cutting		
		10 years	5 years	5 years	10 years	
		Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*
16	Released	2.22	2.26	2.81	2.63	+21.4
10	Left in groups	1.71	1.51	1.44	1.43	−10.9

Trees left in groups continued to decline in growth, as if no cutting had been done, whereas the others were accelerated 20 per cent by cutting of trees within a 60-foot radius. It is thus highly desirable to thin out groups of thrifty merchantable trees.

CUTTING UNMERCHANTABLE TREES

Since the best practice aims to improve the condition and increase the yield of the forest, it follows that while reserving thrifty fast-growing trees, cutting should aim to remove all other trees, whether merchantable or not. The practice on national forest cuttings of removing diseased or mistletoe-infected trees, including many of no merchantable value, is one of the essential distinctions between a merely tolerable practice and one making for full timber crops. Especially in stands with white fir in mixture, there are always some old trees that obviously are mere shells of wood with little merchantable contents. Such trees should be cut for two reasons;

(1) To clean up the area and reduce the risk of infection of the younger trees by wood-destroying fungi.

(2) Equally important, to get rid of worthless trees so that the space they occupy may be utilized by young growing trees. Ordinarily these defective and unmerchantable trees are not desirable for seed production, and it is better to cut them and leave them on the ground than to allow them to occupy valuable space. In short, diseased and defective trees will never have more value than they now have, they are a menace to the soundness of the new stand, and are worthless users of space.

THE COST OF CUTTING RESTRICTIONS

The various steps outlined as essential to the production of full timber crops depart more or less widely from the current practice on private lands and will increase the logging cost if they are put into effect. Studies of the extra costs of logging national forest timber made for the California pine region by Birch (*4*), Berry (*3*), and Price (*12*), indicate that the extra direct costs per thousand feet cut chargeable against Government requirements are:

Extra railroad construction cost, due to reservation of 10 to 15 per cent of stand	$0.375
Marking	.015
Cutting diseased trees	.07
Extra yarding costs	.30
Extra stumpage costs	.30
Total	1.06

Against this charge, however, are certain savings that are easily demonstrated. First is the increased quality of the logs obtained from national forest land, due to the elimination of the smaller trees of lower quality. Data already examined indicate that on private land young and small trees, such as would be left by these measures, are at present usually logged and manufactured into lumber at a loss.

A comprehensive study by J. R. Berry of national forest and private cuttings on the same watershed by the same company, where cutting on the private land was to a diameter limit of 14 inches, showed that the direct yarding cost per thousand on national forest land was $4.92; on private land, with a heavier cut per acre, the cost was $5.45. His conclusion was that this striking difference was due to the cutting of small trees, which were actually logged at a loss.

It seems fair, therefore, to credit intensive practice with the following items per thousand feet cut under usual conditions:

Increased selling price	$0.50
Decreased logging cost [6]	.50
Total	1.00

ESSENTIAL STEPS IN PRODUCING FULL TIMBER CROPS

The essential steps in producing full timber crops, already discussed in detail, may be summed up as follows:

(1) Put into effect the fire protection measures, already discussed as part of simple timber-growing practices. In addition, slash should be piled and burned and snags felled on all cutting areas.

(2) Protect the reserve trees and advance growth during logging.

(3) Leave all thrifty young timber for future growth, treating all species equally.

(4) Cut weak, diseased, and malformed trees whether merchantable or not.

(5) Leave an average of three seed trees per acre where the reservation of thrifty timber does not supply at least this number of seed-producing trees.

THE TOTAL COST OF THE MEASURES

Summing up the debit and credit items, already discussed in detail, the immediate expense of adopting the partial cutting plan is:

Item	Debit	Credit
Fire protection and slash disposal	$0.50 to $0.69	[1] $0.21
Protection to young growth in logging	.07	
Reservation of thrifty trees	1.00	1.00
Cutting diseased trees	.07	
Total	1.64 to 1.83	1.21

[1] From carefully estimated results on one large operation.

The net increase in cost above current practices does not appear to exceed 50 cents per thousand feet cut, a relatively insignificant item in the total expense of producing lumber.

[6] Due to elimination of small trees handled at a loss, both as regards log making and cost of handling.

The indications are, at the very lowest estimate, that the commonly assumed financial disadvantages of partial cutting, as on national forest land, are largely imaginary. It seems fair to conclude that similar cutting on private lands, much as it may depart from the current cutting practice, is not necessarily either costly or impractical.

THE OPPORTUNITIES FOR PRIVATE FORESTRY

The physical steps needed to produce full crops of timber are immediately practicable and are inexpensive. They can readily be taken as part of the logging operation on private lands as they already are on national forest cuttings. The real obstacle to adoption of the measures is neither their difficulty nor cost, but rather uncertainty concerning the future.

Whether or not the owner of forest land goes into the timber-growing business will depend on an answer to several questions. The first of these deals with the productive capacity of the land; the rate at which, under a given method of treatment, merchantable timber will grow. The second is concerned with the safety of the investment; the possibility of protecting the growing forest from fires, insects, and disease. Third, the potential grower of timber must estimate the cost of producing his crop; the initial investment necessary and the carrying costs, particularly fire protection expenditures and taxes. Fourth, some estimate must be made of the value of timber at a time several decades in the future; the amount of increase in the value of stumpage, and the value of species now little prized but which in mixed stands will form a considerable part of the second cut.

These are the elements of the problem that the potential grower of timber faces. Though a mathematically precise answer to any of the questions is impossible to-day, an attempt to approximate the answer is far from hopeless.

The productive capacity of forest lands has already been discussed in a general way. An accurate appraisal of the growth rate on a particular forest property of necessity involves a careful examination of the lands, by qualified men and no general statement can possibly be substituted. Parts of the region produce wood slowly, particularly the poorer class of yellow pine lands of the east slope of the Sierras, but a very large part of the pine region can produce wood at or above the rate which is making the private growing of timber a profitable and attractive venture in the Northeast, in the South, and in other portions of the United States. Except in the coast redwood region and in the Douglas fir region, it is doubtful if the growth possibilities of the better lands in the California pine region are surpassed.

The risk of serious damage to young forests by fire is still high, largely from an inadequate scale of protection and from improper disposal of logging slash. The cost of adequate protection is known, and can not be considered excessive. Proper coordination of Federal, State, and private protection efforts can reduce the fire danger sufficiently to justify private growing of timber, though the hazard can never be eliminated.

The likelihood that insects will cause serious loss of reserved trees on cut-over lands does not appear great, judged by conditions on old cuttings, though damage may occur locally. The future of sugar pine as a potential host of the white pine blister rust, is somewhat in question, but even its obliteration from the forests, which is not to be anticipated, would not be an overwhelming loss, for the other species which would replace it are of recognized value and forest management would still be possible.

It is in cost of production that the greatest apparent obstacle to private timber growing lies, and two elements in particular have acquired a disproportionate importance in the discussion. These are taxes and compound interest. At present the actual tax on most cut-

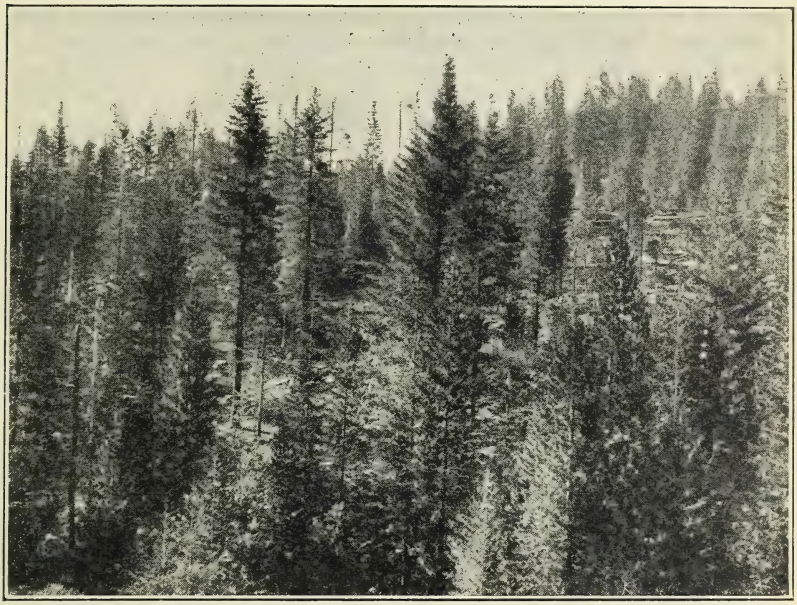

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FIG. 24.—CUT-OVER LANDS AS AN ASSET

By reserving the smaller, thrifty trees, the owner of this forest area has left it producing wood at a rapid rate. A second cut can be made within a few decades.

over lands in California is not high, about 3 cents an acre each year, and this is on many holdings more than returned by income from grazing leases. It is rather the fear of large future increases than the existing situation that deters the potential grower of timber. Fortunately, the principle of special tax treatment of cut-over forest lands has been recognized already in several States, and there is but little question that a solution will be reached in California. In 1923 a tax-relief bill was passed by the legislature, and though vetoed, shows clearly the recognition of the problem and the desire to remove this stumbling block to commercial timber growing.

Even more obstructive is the traditional concept of compound interest as the controlling factor in the cost of production. But, as has already been shown, compound interest is not of importance when timber growing is part of a going logging operation.

It is impossible to tell what stumpage values will be in several decades from now; that is, when the first returns will begin to come in from carefully managed forests. No estimate of the probabilities can, however, disregard the undoubted increased domestic demand for wood, the equally certain decreased supply, nor the inevitable tendency of these two economic factors to increased stumpage values.

In each forest region of the country, stumpage prices have followed substantially the same course. At first, with a plentiful supply of virgin timber, the prices have been low at the start of extensive cutting, rising gradually as lumbering proceeded, and finally, for softwood species, reaching a point of $15 to $18 per thousand board feet as the supply approached exhaustion. Second growth, worth practically nothing while virgin timber was available in large quantities, has suddenly acquired value when the old timber is no longer for sale, and has finally equaled or exceeded in stumpage price the inaccessible remnants of the virgin forest. The final level of value seems to lie above the cost of growing timber, even after liberal allowances are made for costs of production.

In all probability the population of California, which is now growing more rapidly than that of the entire country, will continue to do so for some time. As a consequence the local need for wood is certain to increase rapidly, and since in 1923 the consumption of lumber in California was over twice the cut, it is evident that even with abundant virgin forests a market for second-growth timber will continue to exist. There is every reason to expect that stumpage rates will continue to rise, as they have in every forest region.

In short, although it is impossible to certify now that an investment in timber growing will earn a stated rate of interest, it is equally impossible to state flatly that capital investment will not earn a fair return. If we compare the state of the timber supply, the expected future demand, and the known possibilities for yields with what has happened elsewhere, the opportunities for growing timber at a profit on private lands do not appear absent. Well selected areas, properly protected and managed, on the better sites, should prove a good investment.

The speculative features in the timber-growing business to-day are no greater than in the timber acquisition business of 25 or 30 years ago, if they are as great. At that time it was not at all certain that increasing population and demand for lumber would make it profitable to exploit these forests, and the apparently inexhaustible supplies of the South put the eastern and central market beyond the reach of western lumber. The possibility of serious loss from fire was far greater than to-day, for systematic protection was unknown. The amount of the tax burden and other carrying charges was largely an unknown quantity. In spite of these apparent obstacles, men with boldness and foresight found the acquisition of timber a profitable venture. There is little reason to doubt that the growing of timber will likewise prove a profitable business in the California pine region, as it is in other forest regions. (Fig. 24.)

Neither the Forest Service nor anyone else can say flat-footedly that timber growing is a profitable undertaking for all owners of forest land in the California pine region. This question can be answered only by expert study of each operation, taking account of

the stumpage holding, quality of land, condition of early cuttings, and nature of the business. The opportunities for successful business enterprises in this field warrant such an expert study of the individual holdings or operations.

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